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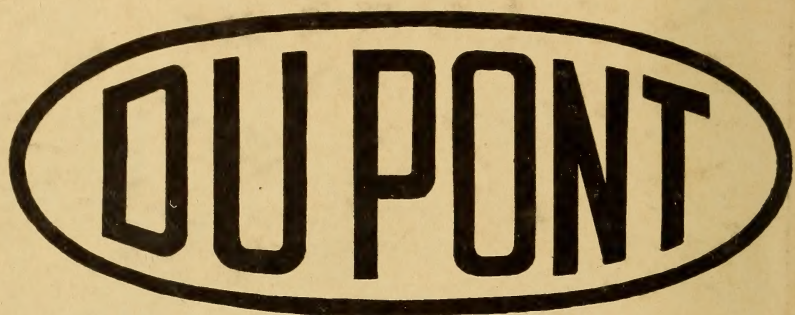
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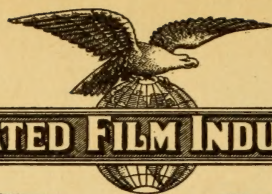
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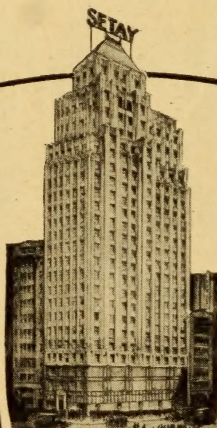
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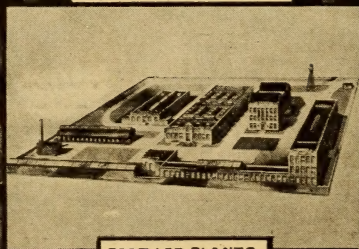
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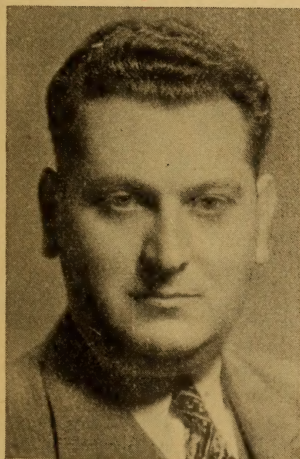
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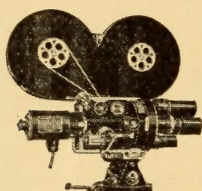
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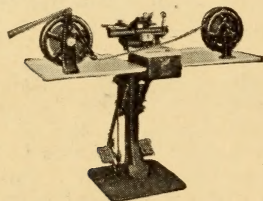
rates, exposes, prints and splices most of the movie film in production today. Not a small part of Bell & Howell's work continues in the direction of research and experiment. A complete engineering laboratory is devoted to the special cinemachinery needs of the industry.

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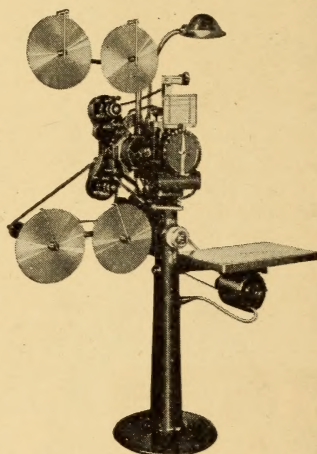
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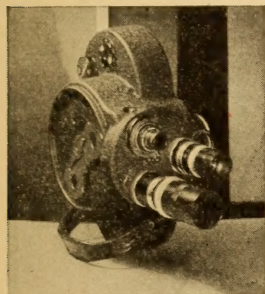
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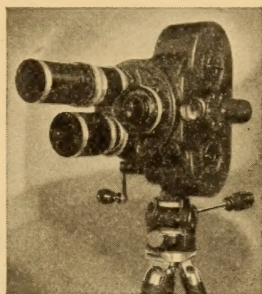
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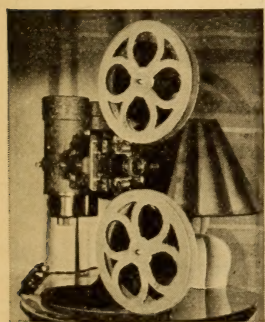
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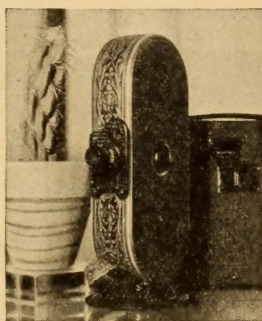


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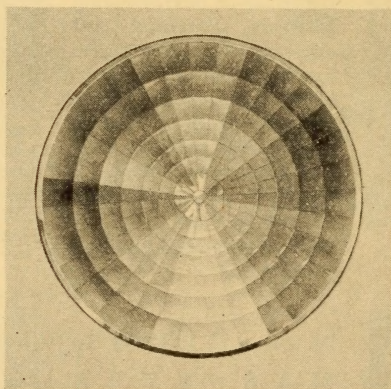
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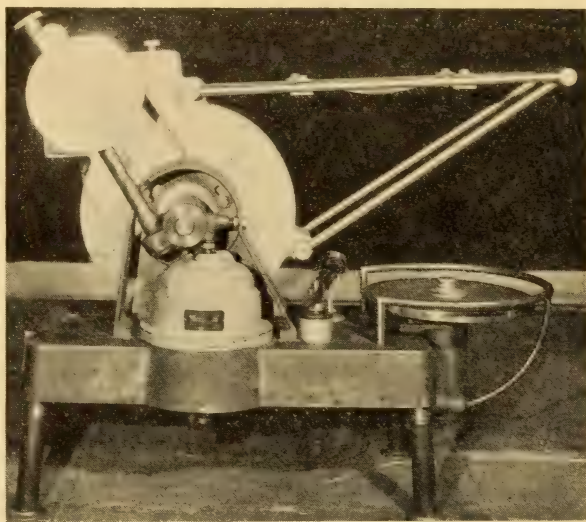
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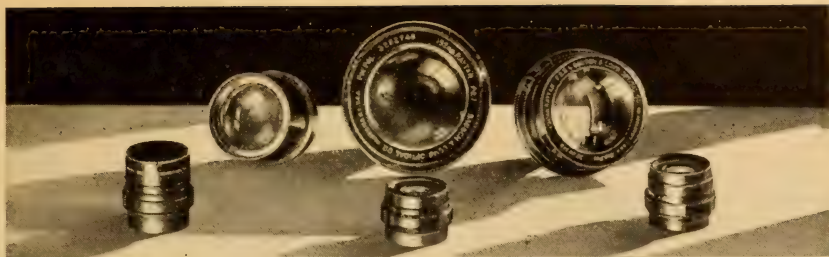
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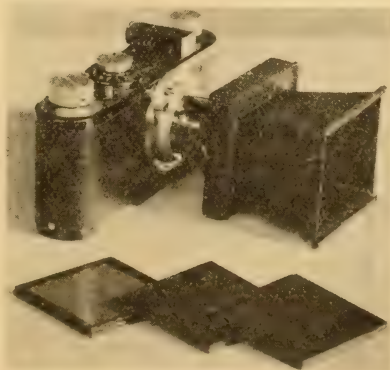
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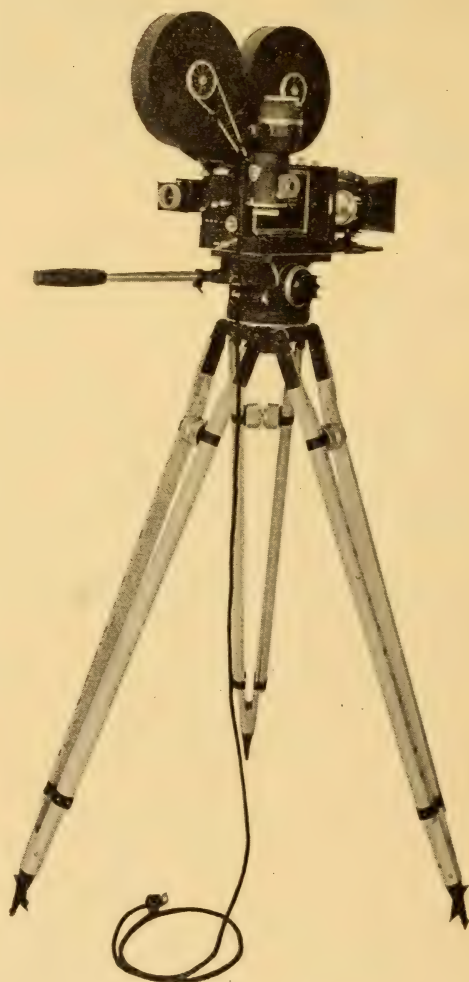
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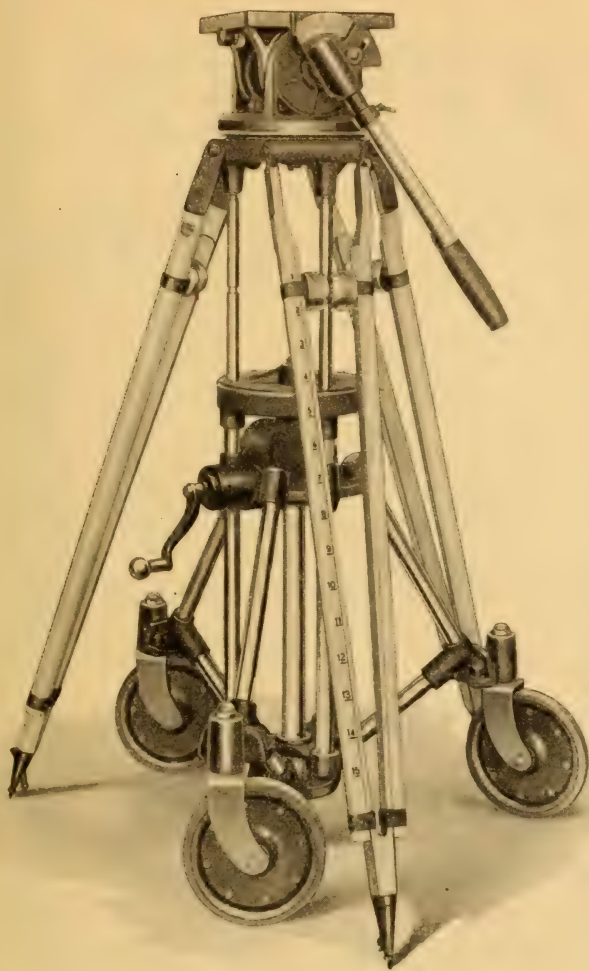


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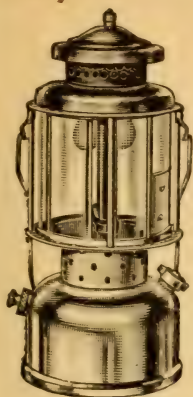
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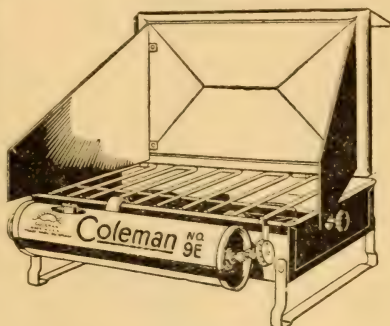
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CINEMATOGRAPHIC ANNUAL

Volume Two
1931



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PREFACE

THE PREPARATION of a volume such as the Cinematographic Annual is a task that requires the cooperation of many minds, and the writer takes this opportunity to express his gratitude to those busy men who have given him their cooperation in no small measure. Without their aid the task would be next to impossible.

In this second volume we have attempted to present an even more varied discussion of subjects than in last year's volume; and we hope that our efforts will meet some of the needs of those interested in these subjects. We have tried to present helpful information for everyone connected with the making of motion pictures, either in the studios or in the home. The pictorial section, which in Volume One brought forth tremendous approval, has been doubled in size in this volume, and a larger number of contributors are represented than last year. Each year we hope to make this Annual more valuable to its readers. If you will write us, telling us the subjects you would like in Volume Three we shall try to cover them for you.

—*Hal Hall, Editor.*

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APPRECIATION

THE success of a publication rests with its contributors, and the past year has seen "The Cinematographic Annual" placed on a new plane of usefulness to the craft it represents.

I wish to express not only my own personal thanks, but the thanks of our organization as a whole, to the writers who made this possible. They have delved deep into technical science to give us new knowledge. They have labored painstakingly in difficult research, to cast new lights on our craft. Theirs has been a Herculean task, and performed for the sheer love of it. No word of thanks, no commendation, can adequately express what they have so unselfishly done for the good of our calling.

I cannot hope, therefore, to fully express our thanks, or the deep sense of appreciation for a work that stands prominently among the scientific tasks of the year. I can only, in my humble way, assure our writers that their efforts have been of a greater value to us, and have aroused a deeper sense of gratitude than mere words can express.

JOHN ARNOLD,

President, The American Society of Cinematographers.



John Arnold

INTRODUCTION

*John Arnold**

ALTHOUGH the past year has been one of the most trying that the motion picture industry has ever experienced, it is gratifying to note that it has been a year of considerable progress as far as cinematography is concerned. As a matter of fact, rather notable strides have been made in this art.

It is difficult to define cinematography, for like the moving picture, it is art, a science and a business. But, at any rate, it is the foundation of the motion picture industry; for in the final analysis, all that the industry has to sell is a succession of individual pictures which, when thrown on the screen, give us our motion picture. Take away the picture, and how salable is your product? Even in these days of depression, nearly fifteen million people daily pay to see the motion pictures. But, if anyone were foolish enough to try the experiment, not even a handful would pay to merely listen to the best sound-track you could possibly produce—if projected without the picture. Therefore, it is highly significant that in the past year the trend of the industry has been more and more toward the return to the old moving picture technique of telling stories with a camera, rather than with just a lot of meaningless conversation.

Dialogue is all right in its place. But the fact remains that dialogue—especially when it is far from brilliant or scintillating—can never take the place of camera technique in telling a story. When sound was first introduced it was a novelty and, naturally, attracted the curious. But it did not take long to bring about a condition where the public tired of mere sound and conversation and wanted to see some of the technique of the silent pictures again—a technique that really tells a story in a fast-moving manner.

It is highly pleasing to note that during the past year great strides have been taken to bring back such a condition in the picture making industry. The first step was the development of light, sound-proof camera housings which restored to the camera something of its pre-sound mobility, thus making it a more useful tool for the intelligent photographer and director. Two creditably noiseless cameras were also developed; one made by one of the outstanding camera manufacturing companies; the other made experimentally by one of the major studios. This was a decided benefit as it enabled the photographer to work faster and more efficiently. Other cameras which are already being proclaimed as absolutely silent are in process of development, and it is hoped that they will soon reach the studios.

Another step has been taken by the production executives themselves. This step has been to cut down on dialogue to a large degree and tell the stories with the technique of the silent pictures. This has been done to a notable degree during the past year, and present indications are that action will more and more replace dialogue in this objective.

*President, American Society of Cinematographers.

While the craze for color, which swept the industry for a time, was comparatively short-lived, it likewise was beneficial to the art of the cameraman. Due to the above-mentioned craze, color photography has been greatly improved and appreciably advanced. It is doubtful if this would have taken place had the demand for natural color pictures not been so pronounced. The result is that today more and better color processes are available than ever before; and the cameramen are more adept in the art of color photography.

Another craze that, for a time, threatened to overturn the industry has also died out—but not until it had focused attention in certain directions that were helpful to the cause of photography. That is wide film. The wide film experiments brought to the front the fact that the industry needed a standardization of projection apertures and forms. The heart of every scene is good composition, but when the photographer was compelled to compose each scene for three apertures of different sizes and shapes he was facing a problem that was next to impossible. Some degree of improvement has resulted, and greater improvement may be expected in the near future. This, thanks to the wide film flurry.

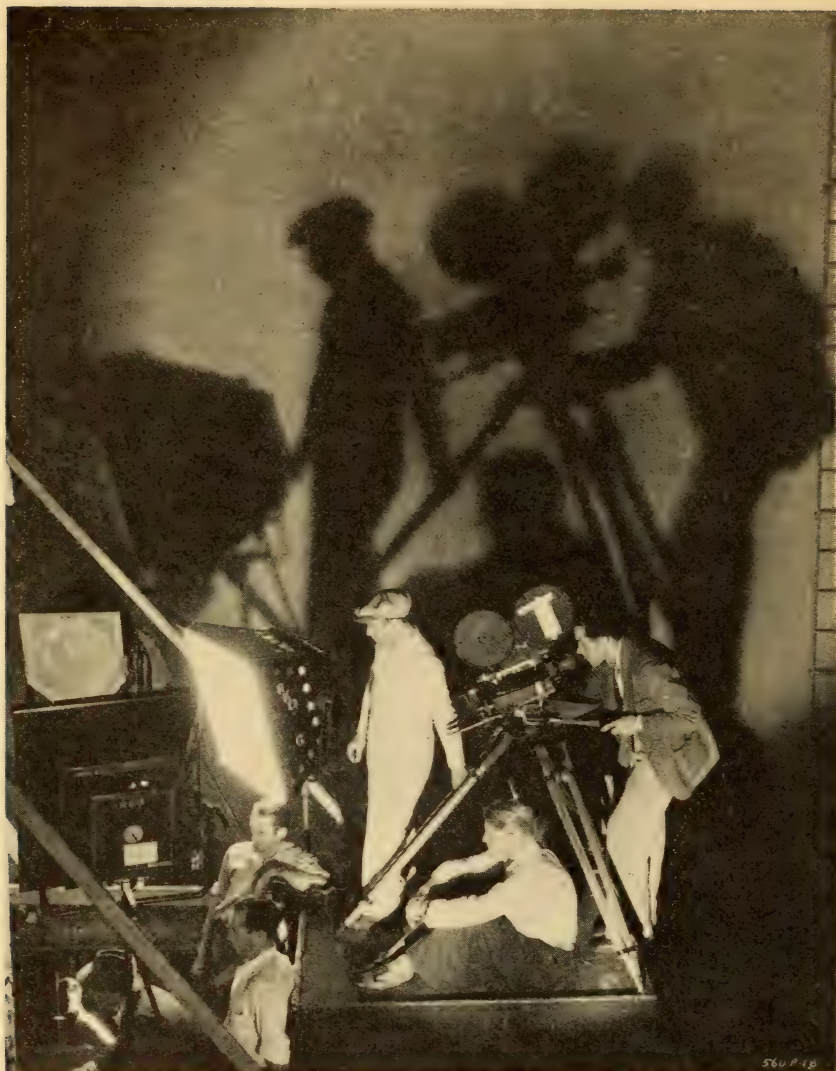
Perhaps the greatest forward step taken in behalf of good photography was the development of the new "fast" film. This new film is characterized by a vastly greater sensitivity which makes possible much improvement, both artistically and technically. Less light is now used on the sets which makes for economy; and the color-sensitivity is such that pictures made with it are far more natural-looking than before. Lighting equipment manufacturers have been keeping step with the film makers and are endeavoring to produce lighter and more efficient equipment. This matter will be given much more attention during the coming year, and vast improvements in this equipment field should result. Laboratory engineers have also been keeping abreast of the times and better results are obtainable. If the laboratories producing the release prints will give a little more care to the product turned out there will be a still greater improvement seen when the motion pictures reach the screen.

Thus, it is apparent that cinematographic progress has been made in the last twelve months. This is encouraging, for when the photographers and the directors—upon whom, after all, the responsibility for the success or failure of each picture rests—when these men stagnate; when they cease to progress, then will the industry as a whole fall backwards. As long as they can go forward, cooperating to make each picture the best of its kind, then neither depression nor panics can permanently impede the progress of the motion picture industry. Upon the perfection of the product rests the whole structure of any enterprise; and in motion pictures this perfection depends upon the alertness, ability and cooperation of the photographer and director.

It is with this above thought in mind that the American Society of Cinematographers publishes the Cinematographic Annual, of which this is the second volume. The cameramen of this organization wish to do all in their power to further the cause of the making of good motion pictures. The society feels that by the publishing

of such a book as this it is taking a forward step in the advancement of not only cinematography, but of all the allied arts and sciences that go into the business of picture making. If the book succeeds in doing this—if only in a limited way—the members of the society will feel that they have performed a real service to the industry.





Shadowland

Robert W. Coburn

THE CINEMATOGRAPHER'S PLACE IN THE MOTION PICTURE INDUSTRY

*Frank Capra**

EVERY now and then some motion picture executive starts a movement to keep the name of the cinematographer off the credit titles of our films. Why?—is a problem that this writer has never been able to solve; for, in my humble opinion, no one—not even star or director—is more worthy or deserving of public credit for his part in making a picture than the cinematographer.

After all is said and done; after all arguments have ended, there could be no motion picture without a cinematographer, for a motion picture is just what the name implies—something that has been photographed. And why shouldn't the cinematographer be given the credit that is his due? To my way of thinking, the cinematographer is one of the most important factors in the motion picture production industry; each year growing more and more important; each year contributing more and more to the real artistry of the screen. Nothing could give me more pleasure than this opportunity to pay him tribute in a publication of the cinematographers, which is a splendid credit not only to him but to the industry as a whole.

In the old days of the silent picture it was a comparatively simple matter to make a picture. You could take most any story and with a series of beautifully photographed scenes turn it over to the cutter and the title writer and, even though you might have wandered from your story, or if the story was very weak, it could be pretty well doctored into good entertainment by the adding of the right titles. In fact, many a story has been shot and completely changed by the titles after it was completed.

But now it is different. Today we must have a real story which is intelligently handled, directed, acted and photographed; for there is the little matter of sound and dialogue which makes it imperative that the job be done correctly—else it will be a bad job. However, the success of your picture depends upon the story. If you have no story you have no picture. The story is given the audience by the characters on the screen who enact the characters in the story. And—not a single thing must be done to take your audience's attention from those characters.

The suffering woman is the center of attraction, say, in one scene. The audience is interested in her and what she is going to do. If you suddenly take that audience attention away from her by a kaleidoscopic whirling of unusual background the audience attention naturally shifts to the background and the story suffers—the picture suffers. So, I have always submerged backgrounds and centered everything on the players. Reality is what is wanted in pictures, not symbolic touches and beautiful settings for mere beauty's sake.

All of which naturally brings me to the point in question—that of photography, naturally, one of the most important elements in the

*Columbia Director of "Dirigible," "Flight," "Submarine," "Miracle Woman".

picture. My own idea of good photography is not that which makes the audience forget the story and gasp aloud at the sheer beauty of the setting; instead, it is the photography that merges itself, so to speak, in the atmosphere of the story. Photography that is not calling attention to itself is the finest photography. And, I want to say right now that the cinematographers of the American picture industry are always striving to do just that. No individuals in the entire production field are so whole-hearted in their efforts to cooperate with me as are the cinematographers.

I believe that the cinematographer should be considered one of the most important cogs in the production wheel, and that the cinematographer should be given the script and know the story long before the start of production; get the mood of the story in his mind, and then keep his photography in the mood of the story from start to finish. A cinematographer can do more than any other individual in the studio in portraying the mood of the story, or he can do just the opposite.

While you hear much raving by the critics anent the photography of many foreign made pictures, I believe that the American cinematographers are the finest cameramen in the world—and one of the reasons for their excellence is the fact that the majority of them do portray the mood of the story with their photography rather than attempt to call attention to themselves by unusual effects which really mean absolutely nothing. A good cinematographer lights his picture so the audience does not realize it has been lighted; gets over the proper effect without the audience realizing he has done it. In other words, an audience should never realize that a director has directed the picture or that a cinematographer has photographed it. That is why "directorial touches" and photographic "scenic splurges" should be kept out of a picture. They detract from the story. Excellence in direction is reached when the audience never thinks of the director's work. Excellence in photography is attained when the audience forgets photography. Excellence in the actor's performance is reached when the audience forgets that it is John Doe and thinks of him as a living character on the screen. Studied poses on the part of the actor may show his striking profile off to perfection but it is poor acting. "Touches" by the director are nice things to talk about but poor direction. Scenic pictorialism by the cameraman makes for some striking individual pictures, but is not good photography. The minute the audience becomes conscious of the "machinery" of a picture, they forget the story. And it is to the credit of the American cameramen that they, as a whole, forget their own pictorial exploitation, and give the finest cooperation in portraying upon the screen the story which could easily be spoiled if these remarkably clever artists used their unusual lighting and composition ability for scenic effects only.

In closing let me say that I feel that the cinematographer should be given more credit than in the past. He is an artist, a hard worker; he constantly strives to develop betterment in technical apparatus as well as technique. In short, he is a splendid adjunct in picture-making who in the past has been more or less neglected.

CINEMATIC TELEOLOGY

Lewis W. Physioc

IN studying the ethical achievements of mankind, we are impressed with the facts that there are a number of elements underlying the motives which suggest that there is a certain nobility of thought represented in each design. These achievements, originally, embody a desire for personal enjoyment of life and the betterment of living conditions. It is primarily an inherent desire for self-culture. During such a process, the powers of observation develop, new forms of beauty unfold themselves, every experience excites a new flow of imagination, philosophizing succeeds passive thinking and happiness passes from the narrow bounds of the purely physical into illimitable realms of mental joys. As new truths are revealed, new beauties beheld, new experiences enjoyed, there comes a mental exaltation that expresses itself in a desire to share this happiness with the rest of mankind and to create an intellectual companionship, which is, perhaps, the consummation of earthly happiness. There is an undeniable ecstasy in producing something that adds to the happiness of others, and of exciting a kindred spirit by so doing.

It is such noble impulses that direct the artist. We should not, at this time, confound such beautiful sentiments with the idea of commercialism. Remuneration is merely the modern equivalent of the ancient custom of patronage, and pensioning of artists. In the modern vernacular, we say that the artist must live, and modern civilization provides that he cannot without the commercial idea of remuneration. As "the pursuit of happiness" is the only excuse for living, this very happiness is the foundation of commercialism. In modern civilization, *we must buy our happiness*. In such a scheme, the artist occupies a peculiar position in offering his wares, because he contributes to that department of human happiness that influences ethical and cultural development of mankind. We can conceive of no greater responsibility that a member of society can assume.

These achievements may represent the purely cultural or spiritual development or the more simple ideas of mere entertainment, which are not to be lightly considered, for recreation, relaxation, alleviation are important elements in the search for happiness. Now when a work embodies all of these elements, it is supposed to be the ultimate of artistic expression. This ambition was ideally exemplified in the early stages of literature, music, painting, and even the drama, where there was an effort to engage the attention by entertainment values and insinuate moral, spiritual, and cultural influences as a subtle accompaniment of the entertainment. There were writers who regarded the writing of a book as a grave responsibility, and considered none worthwhile that did not combine the more lasting influences

with the more fleeting effects of mere entertainment. They held that a mental suggestion so directly offered, as in a book, was a living seed cast into fertile soil, and sure to bring forth fruit, good or evil, according to its nature. Such literature is illustrated in the works of men like Bunyan and DeFoe.

Likewise, the early painters devoted their talents almost entirely to religious subjects, and musical composers were inspired by the purest devotion, and their works reached such dramatic heights, and continued to exert such influence, that even to the present, prosaic age, religious fervor is more easily aroused by those beautiful masses, oratorios and hymns of praise than by any other means. Even the early drama was designed to convey spiritual and religious lessons, as exemplified by the medieval miracle plays, traveling shows, and church performances. These early dramas were recognized as having such a powerful influence on the lay mind that they were not only supported by the church but were actually produced and supervised by the clergy. The themes were taken from Biblical passages, both the old and new Testament depicting the life of the prophets, and particularly the Passion. They also represented allegorical figures of the various virtues. The fundamental principle, in all cases, was the reward of virtue and the punishment of evil. But in all ages, abuses have clothed themselves in the prerogatives of art, and questionable matter has been presented under that elastic patronage that the arts seem to enjoy. This fact is particularly noticed while reviewing the history of the Restoration, that period, succeeding the civil wars in England, which ushered in a condition of utter abandon, which usually succeeds great cataclysms—revolutionary, social, religious, or political. This same condition is being experienced in our present era as a result of the World War. The depression of tragic memories is vented in daring extremes of distraction—at first, out of sheer relief from suffering, but which eventually becomes habitual by unrestrained indulgence.

In all ages there have been these periods of moral independence or social license. This condition has consequently introduced serious social problems, and the drama, as well as current literature, has frequently taken advantage of this condition to resort to extremes in stimulating emotions that have been paralyzed by satiety, rather than expressing the more noble desire of attempting to correct dangerous evil. There is a great temptation to appeal to a craving for sensation, the modern so-called "kick" which always results from these periodic extravagancies in the human race. It is during such periods that sentiment gives place to insouciance, culture surrenders to coarseness, taste succumbs to vulgarity, and impudence becomes strident.

It is easy to see, then, that in all forms of art during such periods of evolution, the entertainment values are recognized as important factors, and with this condition is necessarily introduced commercial complications and there develops, also, temptation to divorce art from moral responsibilities in exploiting the purely entertainment features.

The abuses, among the arts, are not only charged to the commercial exploitation—they are often the result of insidious individuals appealing to the lowest impulses of the popular mind under the hackneyed cry of "giving the people what they want." This moss-grown excuse has been employed to justify the most shocking irregularities. At first these abuses are openly presented and then very cunningly insinuated when attacked by those few who at all times cling to decorum and order, and who have constituted the censorship of all ages. Mr. Sheldon Cheney, in his great history of the drama, shows how Pompey the Great, in answer to that time old censorship, erected over the theatre a temple to invite superstitious awe to aid in veiling the sinister appeal of the theatre. Thus could he dedicate to the Goddess Venus the most shameful immodesties and immoralities, to Bacchus the most disgusting wantonness, while filthy songs, risqué dialogue, sensuous music are offered as invocations to their respective patrons, Apollo and the Muses, Minerva and Mercury, etc. In quoting some of those lines from the ancient Tertulian, we can fancy hearing the indignant tones of our own, more modern, Brieglibls, Shulers, and others.

"Finally, no one entering the show thinketh of anything more than to see and to be seen. What manner of thing is it to go from the Church of God into the Church of the Devil?, from the sky (as they say) to stye."*

This narrative illustrates but a brief period in the history of the drama; the workings of man's mind, for ages, has been very similar as regards subterfuge. This incident, then, furnishes a general implication of the practices among the proponents of the arts over periods of hundreds of years, and is a fairly just foreshadowing of what to guard against in the years to come.

Mentally, it is a very short jump to a like example when the church sponsored such gruesome tableaux as the decapitation and torture of heretics. It is no wonder, then, that kings, with their peculiar powers, should have had their orgies of actualities with such clerical suggestions as incentives. We find, also, that the very effective and legitimate means of illustrating to the laity the beautiful characters and dramatic episodes of the Bible, was soon abused by the vulgar members of the church. Cheney has furnished an amazing picture of this chapter in the history of the drama.

"The pageantry of the Catholic service, the stirring sacred music, the impressive architectural background, the sincerity and conviction in delivery—many a later theatre, though more literary and more professional, fail of importance for lack of these."

"Imagine the porch of Rheims Cathedral arranged for a play like *Adam*. The Paradise is a simple booth built up on the top step within the central recessed portal; it is richly curtained, and stands out as a colorful note against the sculptures and traceries of the monumental facade. The other simple "stations" are placed close by; lowest of all, the yawning Hell-mouth. The costumes make the processions a lovely interplay of movement and color. The music,

* Cheney's "The Theatre."

drifting out from the Cathedral, is doubly impressive as one looks up at the great Rose Window; where else could a heavenly choir be so appropriately concealed? And whence could come the thundering voice of God so convincingly, so nobly? The actors, too—these are no mere mummers, coming from and returning to empty space behind canvas flats; these are the servants of God appearing from and returning to His House. And do they not speak His Word? How then doubt that this is one of the noblest theatres of the world?"

"But even the Cathedral theatre can be desecrated. This time it is the church itself that turns wild and matches the impressive use of the drama at the altar with ribald revelry and profane mockery at other moments."

Then followed the feast of the fools, at Christmas and New Year's time, when all sorts of profanity, revelry and mockery were indulged; when rubber and old shoes were burnt instead of incense; inspiring hymns gave place to vulgar songs; when such beautiful episodes of Biblical drama as the flight into Egypt were parodied, carrying a real donkey to the altar rail—the Alleluia was brayed and the congregation responded with hee-haws.*

Again, we must refer to "The Restoration," further along the years, because it is so typical of our present problems. At that time the art was employed as the voice of opposition—opposition to political measures, protests against social conventions, insurrection against religious doctrines, renunciation of age-old traditions. So bold were those innovations, in all departments of sociology, that the few remaining conservatives were soon up in arms. The result was *Puritanism*, an antagonism against the theatre that has lasted, in more or less degrees, to the present time. Censorship was again inaugurated, and prosecuted with such zeal, for a time, that the theatre had little patronage outside of the aristocracy and the court circles. We can readily imagine the abandon displayed by this peculiarly independent society. The playwrights followed the age-old slogan of "giving them what they wanted." "They bent their sails to the breeze." "For a debauched society headed by a debauched king, the playwrights shaped their entertainment. Nothing could then be in worse taste than a show of human feeling, a suggestion of moral concern, an honest heartiness." Now, extreme impudence, audacity and utter disregard for conventions always result in a powerful reaction. There are influential minds that look on complacently, for a while, at such opposing forces, i.e., license and censorship, and only shake their heads disapprovingly, as if watching two ill natured children quarreling; but when it appears that the combatants are going to injure themselves and cause real grief to others, the strong arm of wisdom and order intervenes and in a manner that carries conviction. Some one raises a cry that all respect. The results are a sudden rally to his support, a concerted, organized campaign. Then comes *Prohibition*. Witness the closing of the theatres following those above mentioned extravagancies. Witness some of our own blue law communities—our own dear historic Prohibition. Such conditions im-

* Cheney's "The Theatre."

mediately create two bitter factions. On one side we find reform sympathizers opposing institutions that might be so ordered as to furnish happiness for all, and on the other the stubborn followers of those institutions using every device to defy the opinions of their opposers, instead of trying to fill the breach by ordering things to the general weal.

It is readily seen, then, that the tendency is to invite a specific following and to produce works that appeal to this patronage. It is just as likely, also, that this patronage becomes more and more tolerant of extravagances and abuses. Money lust enters into the scheme of things, and depravity is commercialized to the limit. The same old wheel of indulgence swings around, seemingly proving the existence of an indissoluble problem. This is why reforms are continually demanded.

Art and the Drama

When we come to consider the application of the principles of art to the drama, we wonder how we can review past achievements and connect them with our hopes for future developments, in order to estimate our ambitions in regards to motion pictures.

The so-called modern ideas in art have long since invaded the dramatic field and there have been spasmodic attempts exhibited in the pictures.

Just what is this nouveau art that we hear so much about? What is its generic impulse? Is it merely the modern craving for notoriety, the applause that rewards the conception of new ideas, the enjoyment of producing something that sets the conservative world by the ears? Or is it really some new development of nature that is gradually giving to man a new fourth dimensional twist of the brain, which leaves the hitherto unendowed with a helpless feeling of unfitness to meet the new order of things artistic? Even those who love to think that they have a great breadth of perception and can interpret hidden beauties, begin to doubt themselves when reviewing some of the examples of modern art. They refer suspiciously to those lines of Shakespeare:

—"tongues in trees, books in running brooks,
Sermons in stones, and good in everything."

Those who have spent years and years in the class rooms of the various academies, patiently and industriously trying to reproduce the conventional ideas of beauty, feel a helpless uneasiness in the presence of those who rave over drawings of what to them represent childish crudeness, unaccountable distortions of familiar forms of beauty, crazy perspectives, "goofy" angles of vision, violent modulations in the scale of color harmony. They begin to question as to whether these exhibitions are an erroneous distinction between the old school of painful realism and simple, direct expression, or if they are unfortunately the sloughing off of an ancient species of man which is bridging the evolution of the new super, "fourth dimensional" mind. In the shame of a rapidly approaching "inferiority complex" we seek for enlightenment. We turn, in sadness, from our idols and

look jealously, as well as zealously, for the truth in these new things. We blush at our incomprehension. We acknowledge feelings of resentment when, in our search for understanding, we resort to periodicals devoted to these advanced ideas of art, and read involved and extravagantly phrased criticisms of their material. We cannot but speculate as to whether it is all sincere or a subtle exposition of something that is thrust upon them and which they must make the best of. And even the proponents of this new school do not seem to discourse well upon it. We have read a disquisition by a modern school celebrity in which he attempts to analyze those emotions that urge his activities. He describes as always having before him, as an inspiration, one of the masterpieces that has enjoyed the veneration of all lovers of art since its creation. He very ably presents an appreciation of its merits—its fidelity to natural form, the simplicity and dexterity of technique, its tenderness of impulse, harmony of color, the soul of the artist. Our enthusiasm is aroused, our chilly reaction to modern art begins to melt, until we behold some examples of the work which the old masterpiece had inspired. We then feel like the child who watched with delight a magician's trick and suffers disillusionment by seeing it immediately exposed.

We begin enquiries as to whether or not this school of art is the result of a peculiar departmental complex of modern civilization. During the last fifty years, the evolution of ideas has been kaleidoscopic, and the authorship of these new ideas is the ambition of students—the conception of a novelty is the passport to recognition, and recognition is a ruling passion. Is this school of art a straining after something new in a noble scheme where novelty is not the primary moving force? It may be that we live in such an insouciant age, that something of this sort is required to arouse us. Have modern institutions discouraged sentimentalism? Have the rapid developments in science and mechanics impoverished individual effort and diminished sincerity? If so, we might be justified in imputing to modern art, also, a lack of sincerity, or, at any rate, that restless impatience (characteristic of the present age), with the very trying curriculum of the artist—the modern craze for direct and immediate expression. Such speculations lead us to refute the assumption of a so-called modern art. Let us contend, rather, that there are *two* forms of art, and make no distinction as to modern or antiquated schools. We may call them Graphic art and Recondite art.

By Graphic art, we allude to that form whose proponents still cling to the idea that art is, primarily, the contemplation, production, and expression of things beautiful, the nobility of thought back of its literary design, the purity of its emotional appeal, and a sincere acknowledgment of the training necessary for the mastery of a specific department; and above all, its cultural influence. As an example, we imagine an artist being inspired in the choosing of a subject and executing it to a degree that entitles him to the same admiration accorded the serious efforts of his brother artists. This type of artist existed in past ages, exists today, and will always exist.

By Recondite art, we consider those vagaries so hard for some of

us to comprehend—that have suggested some of the hoaxes that have been perpetrated on pretentious admirers and critics of this school. In this category we place any egotistic play for sensationalism, extravagant efforts at novelty, paranoic expressions, abuse of those very legitimate ideas of simplicity of technique and impressionism in painting, crude childish drawings.

In supplying examples of this form of art, we may recall such subjects as a cylinder with four ball-like appendages, entitled, "Torso of a Man". Some strange looking creature with a shock of red hair entirely covering the face, called, "The Portrait of a Lady", in which we search like in a picture puzzle, for a semblance of a face, and helplessly ask, "a portrait of who?" and the modern enthusiast answers, "why, that is left to the imagination, a portrait of your mother, your sweetheart, or your sister". All this can best be illustrated by looking at a drawing by your baby boy, who has expressed very directly with his childish outlines, and the aid of our imagination, an aeroplane dropping bombs on a peasant's house.

Influence of Modern (Recondite) Art on the Drama

Our modern impetuosity and impatience may suggest the question, "what has all this to do with our present subject?" It is designed to show that all forms of art have their parallel problems, and that the stage and screen is no exception. They have, likewise, indulged in abuses. The stage has had its run of such problem plays as "Maternity," "Damaged Goods," "Mrs. Warren's Profession," etc., which have drawn from Mr. Cheney the expression, "thus is the stage made to do for clinic and rostrum. We all went to see these plays and I think we considered them 'advanced'. But essentially the stage is more concerned with beauty than with morals. The theatre is the house of emotion, of passion, of ecstasy rather than the house of correction".

We have also been sated with the sex question. We are going to continue to observe these extravagances until all the institutions which we have held so dear have become so cheap that they will no longer have any appeal. Then will come a reversion of affairs when all these values will be readjusted, chastity, virtue, simple beauty, cultural elegance will again be reversed and sought. We will have our own present-day Johnsons, Goldsmiths, and Addisons to bring back a little sweetness and beauty to our literature, our Sheridans and Garricks to dignify the stage, we already have our Grimaldi in our beloved Chaplin.

In the matter of production, Recondite art has likewise invaded the pictures. We have witnessed strange ideas as regards settings, angles of vision, proportions and amazing elaboration, and the same extravagances are exhibited in the various other departments, literature, costuming, music, etc.

Nevertheless, concurrent with such modernity, there are productions, now and then, that furnish all the demands of the conservatives. They come to us at a time, like such plays as Ibsen's, in his time, and seem to prove the possibility of answering a general demand

for realism, the problem play, a little bit of the touchy stuff, and yet exploit sufficient beauty and sweetness to complement the more sordid expedients.

Now all of these findings lead us to believe that there always was and always will be a radical to taunt the conservatives. We must let them both have their way of thinking, because thought is the only independent element in life. Therefore let us recognize *both* of these schools of art. Let us not bother those who love their Gordon Craigs, Adolphe Appia and Norman Bel-Geddes. But we must also furnish a little for those who still cling to their love of the more Graphic forms of art.

Legitimate Expedients

The stage, and especially the picture, have been narrowed down to an uncomfortable degree, as regards dramatic artifices. How often have we sat in the projection room and heard the boss say, "you can't use that." "Why?" answered the director, "there's nothing offensive in that." "Nevertheless, the censors will cut it out". Then the despairing answer, "what are we going to do, there's nothing left to make a picture with."

What has been responsible for this? The same old thing that has always existed. There is always a type of mind that never knows when and where to draw the line between reasonable propriety and inexcusable flagrancies, and the entire order of things must suffer on account of this particular type. Long ago, Addison wrote on just such a subject, and his thoughts are peculiarly applicable to the present.

"There is nothing which delights and terrifies our theatre so much as a ghost, especially when he appears in a bloody shirt. . . . To delight in seeing men stabbed, poisoned, racked or impaled is certainly the sign of a cruel temper; and several antics represent us as being a people that delights in blood.

"I do not find fault with the artifices above mentioned when they are introduced with skill, and accompanied by proportionable sentiments and expressions in the writing. Far be it from me to think of banishing these instruments from the stage; I know a tragedy could not exist without them. All that I would contend for is to keep them from being misapplied. There may be a proper season for these several terrors; and when they only come in as aids and assistances to the part, they are not only to be excused but to be applauded."

This condition prevails more in the field of motion pictures than in any other department of art. It is due directly to the very wide distribution, compared to other forms of amusements. It is considered, by the moralists, particularly serious on account of the younger element predominating the motion picture patronage. Another point to be considered is the fact that whereas the pictures are considered the chief offenders, those among the producers who exhibit the best intentions are the principal sufferers. And the other branches of art, while not as extensive in their appeal, aggravate the situation con-

siderably. We cannot even acquit the aforementioned examples of *Recondite art*, particularly those examples that picture grossness, coarseness, and vulgarity. Chief among the offenders are the billboards that advertise the very motion picture. Here we find ideas insinuated, or suggested, that are not even to be found in the films. Such ideas, that if really found, would justify the protests of those so deeply concerned about their moral influence. Nor can we even excuse the newspapers that are inclined to ballyhoo anything of a sensational nature. Even our courts are not immune from their contributions of these questionable influences. Let the newspapers give notice of a racy divorce suit, or a sordid murder trial, and the sensation seekers, who rush there, can never be accommodated.

We cannot blame the dramatist, then, when we see him worry, and hear him complain of being deprived, one by one, of his precious artifices, especially when he realizes that the tools of his art have been reduced because of those few who resorted to inexcusable abuses.

We recognize an honest intention, at least, when we hear the hampered writer defending the expedients of his art, such as the quotation from Dumas (the son):

"I realize that the prime requisites of a play are laughter, tears, passion, emotion, interest, curiosity; to leave life in the cloakroom; but I maintain that if, by means of all these ingredients, and without minimizing one of them I can exercise some influence over society; if, instead of treating effects I can treat causes; if, for example, while I satirize and describe and dramatize adultery I can find means to force people to discuss the problem, and the law-maker to revise the law, I shall have done more than my duty as a poet, I shall have done my duty as a man."

Department of Motion Pictures

In discussing the ambitions of the motion picture, its proponents are discouraged by its very complexity; its embodiment of so many forms of art; its brief history and its rapid evolution; its novel appeal. Its novelty, alone, blocks our efforts to establish standards of merit, to estimate its real influence or impose its responsibilities. Among the other arts, we have ages through which to trace each one's history, study its standards, emulate its ideals, take advantage of its appeal and profit by the mistakes and abuses. In each instance, we have well-defined schools of technique to study; individual proponents to inspire us and evidences of cultural influences to guide us. In fact, among all the older forms of art, individual effort predominates their histories. We cannot discourse of music without the overwhelming insistence of particular names among composers, and those whose skill in execution and interpretation are almost equally associated. The same is true of painting, literature and even the more complicated art of the drama, which more nearly reflects the problems of the motion pictures. Even in the drama, we can satisfactorily classify its components, charge its responsibilities, and patronize its individuals, and with the aid of these facts, we can likewise divide its ambitions and measure its cultural influence. But

there is no other form of art in which we find greater difficulty in associating an individual name with its merit than in the motion picture. Our producing companies are very complicated organizations. Here are many, many heads that find it difficult to reach an agreement on important matters; many, many underlings that find it easy to shift responsibilities; writers whose efforts are so scattered, divided and shared with others that there can be no individuality. There are the actors, who have very little choice of their material and who are frequently miscast.

To fully realize this, we have but to recall the credit cards of some of our motion picture titles:

"This or that" from the book of "So and So".

Continuity by "Who's This".

Dialogue by "What's His Name".

Directed by "Who Soever".

Assisted by "Another Fellow".

Art director "This One".

Special effects by "That One".

Supervised by "Some Onelse".

Photographed by "Any One".

Assisted by "Another One".

"A Such and Such a Production"

Contrast this with the simple signature of Anthony Van Dyke, in the corner of one of his pictures, or the author's name on the title page of a book.

There are a few individuals with whom we can associate a definite idea of motion picture ambitions. This is delightful to consider, for we can look forward, with some assurance, to the activities of these few. We feel that such individuality is going to dominate every department, every detail of production will reflect that specific genius. We are sorely tempted to cite a single instance and to intimate that when we go to view a Charlie Chaplin picture, we are not concerned about the credit sheet, for we know that Charlie is not going to have anyone around who cannot contribute something in the general reflection of his genius. We can imagine a very simple organization, "Chas. Chaplin, assisted by his peculiar and particular staff".

Such a scheme approaches very nearly to a definite representation of art, with all its responsibilities fixed, with all its merits satisfactorily awarded, with its individuality marked beyond a doubt. Such an order of things approaches, very nearly, the plans of Gordon Craig, who threw the bomb of independent conception upon the modern stage when he said:

"The reason why you are not given a work of art on the stage is not because the public does not want it; not because there is not excellent craftsmen in the theatre who could prepare it for you, but because the theatre lacks the artist—the artist of the theatre, mind you, not the poet, the painter, the musician".

"Several directors instead of one, several opinions instead of one".

"Now, then, it is impossible for a work of art ever to be produced where more than one brain is permitted to direct; and if works of

art are not seen in the theatre, this one reason is a sufficient one, though there are plenty more”.

The motion pictures, in a comparatively few short years, have passed through many interesting phases of evolution, from the penny peep-show attraction and journalistic report of prize fights to the embryonic foreshadowings of their present day developments; through complicated commercial juggling to elaborate producing and distributing organizations. There has been that period of ultra realism, competition among producers in elaboration, bidding for and exploitation of the stars. It finally reached a stage where it seemed that technical expedients were exhausted, dramatic ideas were beginning to redescribe its circle of repetition, story revivals, and there seemed nothing left, in the way of novelty, except the degree of daring in the presentation of sensationalism, or a few new personalities which resulted from the inevitable fading of the stellar lights.

This uneasy condition was greatly relieved by the development of the sound adjunct, and now we have no immediate worries until we have passed that period of quasi-novelty, of rehashing old materials, redressing them in the new mode of the talkie device, when the talkies will have talked the new enthusiasm into an artistic conservatism, when this new device will become but another pigment on the artist's palette, another brush for the distribution of those already in use. But the great question arises; who will be the artist? Will it be big producing organizations, “giving the public what it demands”, following the same old formulae? Will it be such organizations freed from the great army of personal following, choosing their staff with a sincere desire to exploit the best talent available? Or will it be the independent individual, such as Gordon Craig suggests, an artist making a picture first for himself, and next for his backers, and if his public doesn't like it, it will be very strange, for an artist is his own most earnest critic and when he is honest with himself, he has a big average success with his public.

Shall our writers be of that type who are continually searching around for some sensational idea that goes the rounds of the publishers until it falls into the hands of one whose policies reflect the same ignoble appeal? Its title boldly suggest its motives, and it finds its way into the hands of readers of like tastes. The critics condemn it, and by so doing, advertise it for the benefit of those continually seeking such matter.

Or shall it be he whose idea has been inspired by some unique experience, some sympathetic phase of his contact with life; some great moving problem. It becomes his obsession, an urge that overcomes all indolence, he writes because he cannot help it. He uses every dramatic expedient to force attention to his subject; his words have an eloquence that comes only with conviction and much thinking; they reflect sentiments that are his inherent characteristics, for the most convincing portrayals are those that are deeply felt.

In our concern over the ambitions of our beloved picture business, we must not overlook the importance of good, clean, rousing comedy; we cannot estimate its value to society. But we must distinguish

between coarse, vulgar suggestions and real comedy situations; between wise-cracking, shady dialogue and genuine wit and humor. Comedy is a rare and valuable gift, both as to creative talent, and characterizing and interpreting. Truly, this is the department for which we may well feel concerned, for the outstanding individuals are few, especially among the females. Our present geniuses cannot live forever, except in our memory; who will be our next Chaplin and Lloyd, Normand and Fazenda?

The foregoing reflections are to no purpose if they have not aroused us to a realization that the teleology of motion pictures is worth consideration. The motion picture is a tremendous institution, and must have a considerable cultural influence. If any one doubts this, let him travel in foreign countries and study its effect, learn what are other people's impressions of us as gleaned from our pictures.



CHROMATIC CORRECTION IN CINEMATOGRAPHIC LENSES

A. Warmisham*

RECENT years have been marked by a general adoption of panchromatic films in the studios and the corresponding reaction on lens design and correction. Opticians never cease in their efforts to improve chromatic correction and also the correction of the spherical aberration which is inseparable from it.

The means for precision measurement of chromatic aberrations will first be described. Figure 1 shows an optical bench specially adapted for color testing, and Figure 2 shows schematically how it works. The group on the right comprises a monochromator; light is con-

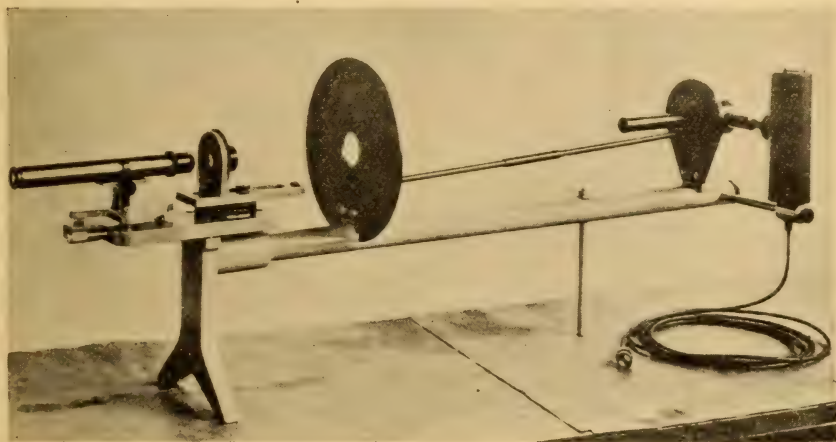


Fig. 1. Optical bench for color testing

densed on the first slit A, whence it is picked up by a collimating objective B, passed through a dispersing prism C, and focused by another objective D, in the plane of a second slit E, as a continuous spectrum. Any desired wave length could be projected through the second slit by rotation of the dispersing prism, but in this particular apparatus the dispersing prism is immovable and the different colors are projected through the second slit by means of a set of auxiliary prisms which displace the spectrum to the desired amount. These auxiliary prisms are conveniently mounted in a turret which is operated from the observer's end of the instrument so that one can

*Optical Director, Taylor Hobson Company, England.

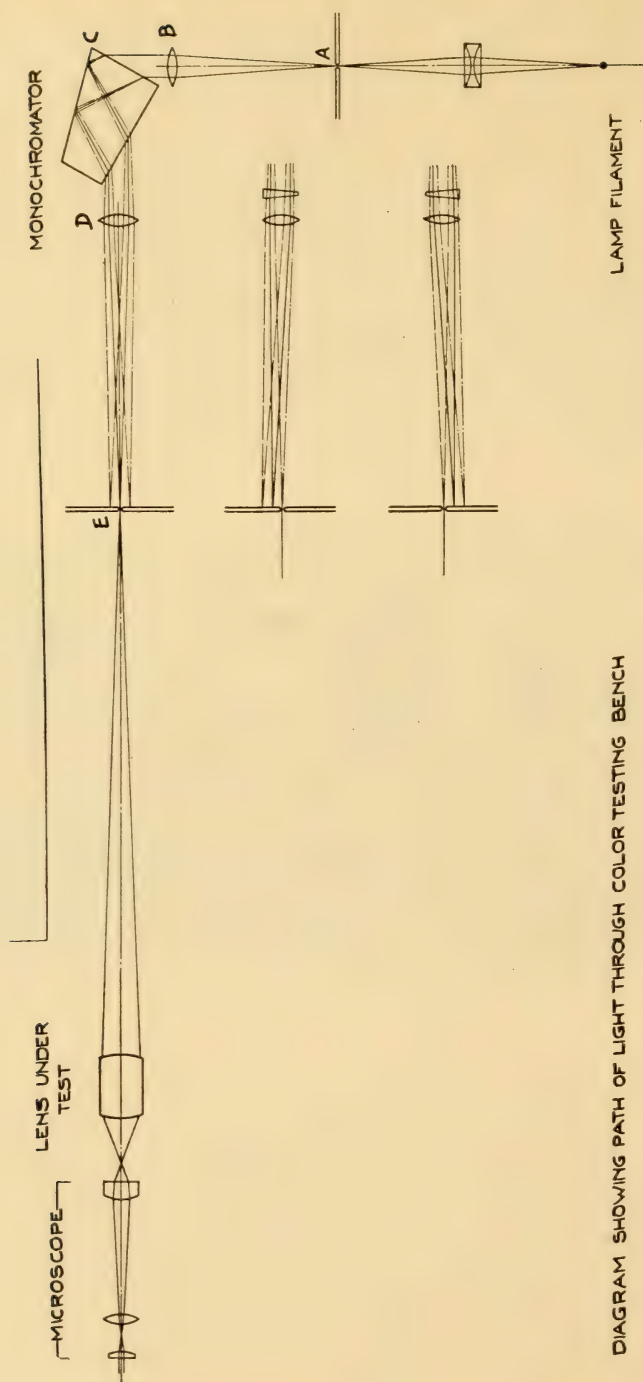


DIAGRAM SHOWING PATH OF LIGHT THROUGH COLOR TESTING BENCH

Fig. 2. Schematic drawing of optical bench for color testing.

instantly switch over from one color to another. Light from the second slit is received directly by the objective under test and the image it forms is examined by an apochromatic microscope. The objective under test is mounted on a nodal point slide of usual form and the examining microscope is mounted on geometric bearings and can be moved axially by a micrometer screw. A horizontal graticule in the microscope eyepiece is used to measure the error of chromatic magnification.

The small bench shown in Figure 1 was designed for the routine testing of the 1" f/1.8 Cooke lenses used for Kodacolor. The distance between the second slit and the objective is about 40 inches and the auxiliary prisms are designed to give the dominant wave length of the three sections of the Kodacolor filter. In Figure 3

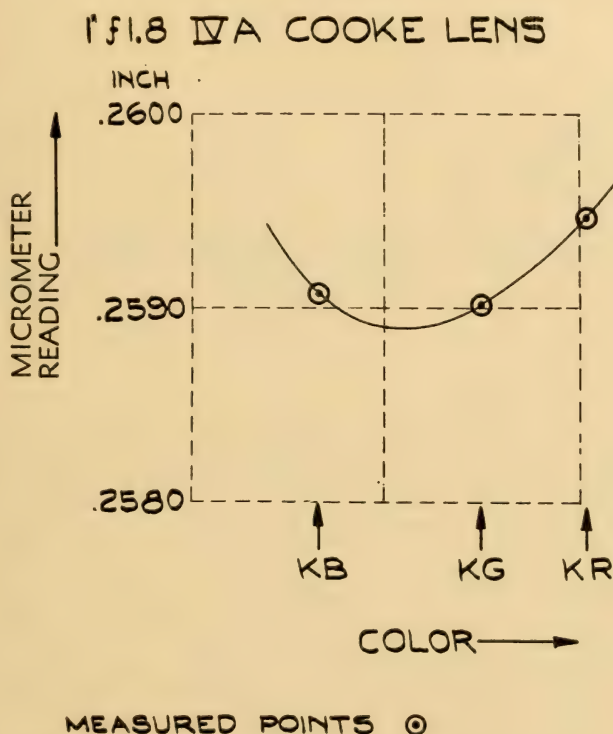


Fig. 3. Graph of secondary spectrum. 1" f/1.8 IV A Cooke lens

is shown a specimen result of measurements on the 1" lens, the vertical scale showing micrometer readings from an arbitrary zero, and the horizontal scale showing the Kodacolor wave lengths—the red, green, and blue denoted by KR KG KB respectively.

The visual indications of such instrument must be supplemented by corresponding photographic tests. Figure 4 shows a convenient arrangement for this purpose. The object is ruled with horizontal parallel lines and it slopes at 45° to the horizontal lens axis. The center of the object is marked with a double line and the lens is focused on this. In an ideally corrected lens the photograph would show a central double line quite sharp and a regularly decreasing sharpness of the lines above and below. If some other line is sharper than the center one on which the visual focus was set, it gives a measurement of the displacement of the chemical focus from the visual for the particular illumination used in the test. For example, in testing a 2" lens, the distance from the center of the object being 8 ft., suppose the second line long was the sharpest in the photographic image. The lines on the object are 1" apart and hence in the above the displacement on the photographic focus from the visual $(2/96)^2 \times 2 \times .71 \text{ inch} = .00056 \text{ inch}$.

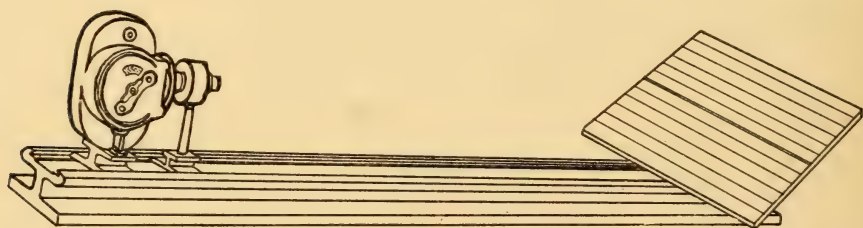
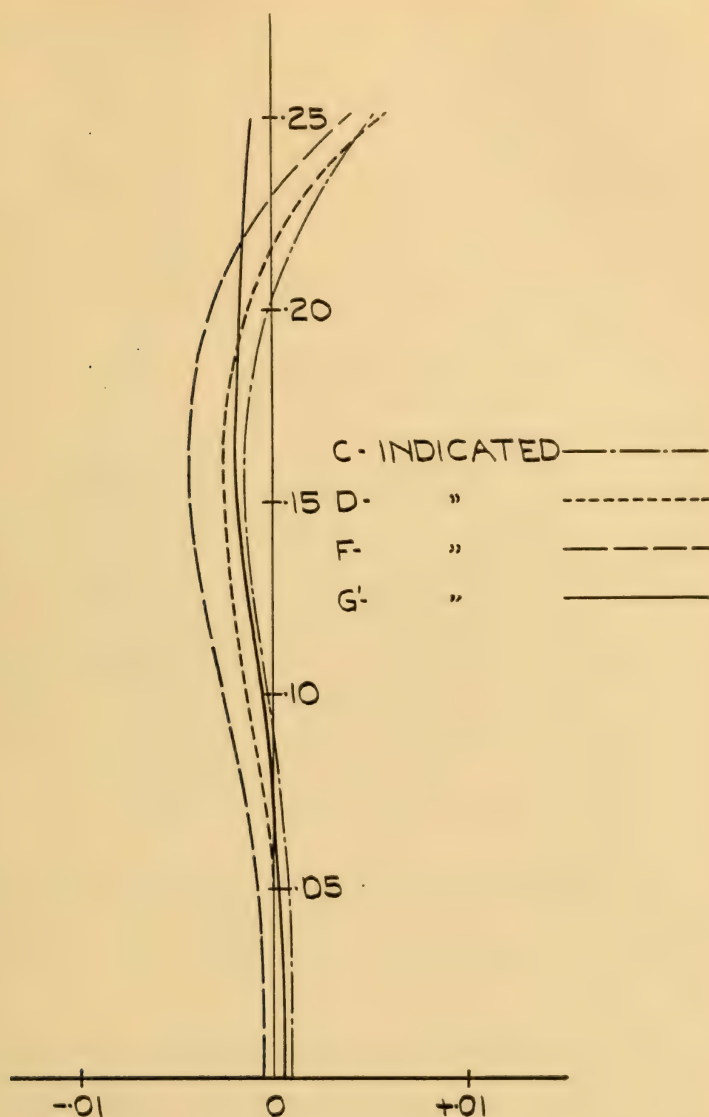


Fig. 4. Photographic test for chemical focus

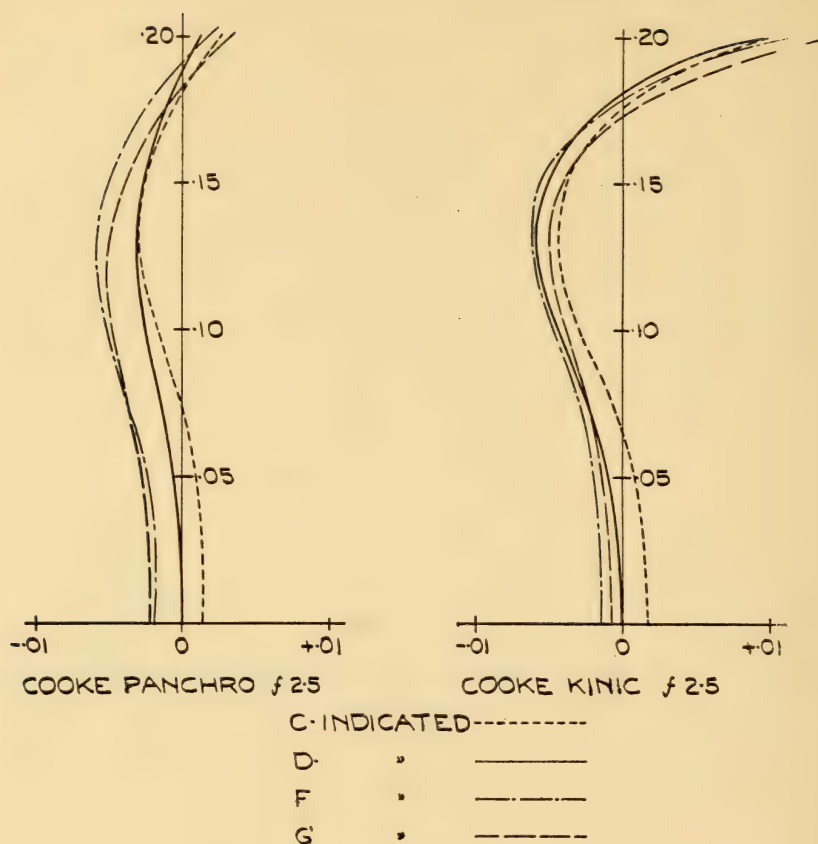
In the routine testing of lenses for professional work an arrangement shown similar to that in Figure 4 is used, and the usual illuminant is the 1000 watt Mazda lamp. The objective is mounted in a solidly built special focusing mount which is fixed relative to the object. A microscope giving X160 magnification is attachable to the rear of the focusing mount to set the visual focus, and the microscope can be replaced by an Eyemo camera in which the clearance between the pressure plate and the aperture has been taken up.

All such tests, visual and photographic alike, measure the secondary spectrum at full aperture. This is not quite the same thing as the paraxial secondary spectrum which is usually discussed in text books. Secondary spectrum at full aperture includes paraxial secondary spectrum modified by spherical aberration which is different for the different colors. To effect any substantial improvement in the full aperture secondary spectrum is one of the toughest problems in optics. Figure 5 indicates the calculated aberration curves for the four spectrum lines C D F G for the Cooke f/2 Speed Panchro lens. This and the subsequent similar curves are all given for a 1" focal length lens.



COOKE SPEED PANCHRO-1" LENS
ABERRATION CURVES FOR C, D, F, & G'

Fig. 5. Aberration curves. $f/2$ Cooke Speed Panchro



SPHERICAL ABERRATION CURVES FOR C,D,F,&G'

Fig. 6. Aberration curves, (A) $f/2.5$ Cooke Panchro lens. (B) $f/2.5$ Cooke Kinic lens

As an example of recent progress in improvement of full aperture secondary spectrum, in Figure 6 is shown similar aberration curves for the Cooke Panchro $f/2.5$ 1931 design and its predecessor the Cooke Kinic $f/2.5$. Comparison of these two sets of curves shows one method of attack. The improvement shown is definitely not in the paraxial secondary spectrum, but a substantial improvement in the general zonal spherical aberration coincides with a modification of the difference in the spherical aberration for the different colors, and the result is a useful reduction of the full aperture secondary spectrum. Both the $f/2.5$ lenses mentioned, as well as the Cooke $f/2$ Speed Panchro, are the work of the Taylor Hobson mathematician, H. W. Lee.

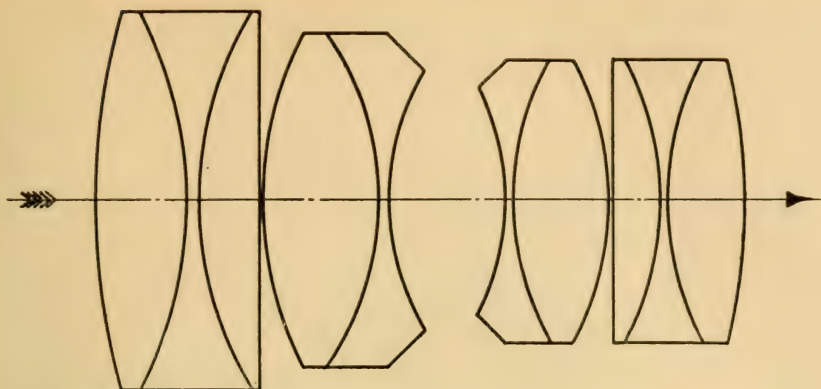


Fig. 7. Cooke lens as modified by Lee to improve secondary spectrum

Another method of attack which has not yet been fully worked out includes the use of special flint glasses in place of the ordinary flints. In British patent No. 321,078, Lee describes a complex objective of the general type of the Cooke Speed Panchro, but including the most favorable of the special flint glasses procurable at the time (1929). The lens is shown in Figure 7. The great complexity of the construction is a measure of the unsuitability of the available material and is further the source of disadvantages which render the design commercially unusable.

Nevertheless it is along such lines that progress will come, and the recent production of a new special flint of favorable optical properties brings into sight improvement along these lines.



Ned Van Buren, A.S.C.

MAKING A FADE-OUT BY AFTER TREATMENT*

C. E. Ives, L. E. Muehler and J. I. Crabtree

THE fade-out and (fade-in) has been used extensively to cause a pleasingly gradual transition between successive scenes in a motion picture and is regarded in many cases as a necessity for artistic presentation of the picture story. The fade-in and fade-out are essentially similar in nature although opposite in arrangement so that, for convenience, only the fade-out is referred to in this paper.

The fade-out can be defined as a process whereby the picture is made to disappear from view by a diminution of brightness and contrast of the picture toward the end of a scene.

For many years fade-outs were made in the camera by decreasing continuously the light which reached the film through the optical system as the end of the scene was approached. Thus, as the fade-out progressed, the negative was more and more underexposed until at the end of the scene no image whatever was produced.

When a print is made from a negative which contains a fade-out the printing exposure is not varied within the scene so that the frames included in the fade-out are progressively more dense and deficient in contrast. When such a fade-out is projected on the screen the "fading" is seen to consist of the disappearance of, first, the shadow detail, second the medium tones, and finally the highlights.

As the art of editing developed it became necessary to make the fade-out in the developed negative after the cutting process was completed. This necessitated either the insertion of a duplicate negative in which the fade-out was produced in the same manner as in the camera, or the alteration, by chemical treatment, of the original negative. In the latter case photographic reducing solutions were used to produce so-called "chemical fades."

Recently it has been considered desirable to insert fades in their proper places in the editorially cut print so that when it is viewed for final approval it is complete in all respects. Any cutting or alteration is done in the negative after this print has been approved. A method has been developed for making the required fades in the positive and will be described in this paper.

The Nature of a Fade-Out

The first requisite of a good fade-out is that it shall cause the picture to disappear in a gradual and continuous manner. If it is abrupt or has the appearance of being discontinuous, it does not serve the function for which it is intended. The fade-out must begin at a certain frame and go to completion between this point and the end of the scene. The average rate of change of density is determined

* (Communication No. 475 from the Kodak Research Laboratories¹).

by this length and the maximum density change which must be effected. The course of the change should be such that when the picture is viewed by projection the average brightness appears to diminish at a uniform rate.

If the change in brightness is to appear uniform, the density of each frame should be related to that of the next by an approximately constant difference. This is because, in general, the eye appreciates as equal steps in brightness those which are related to each other by equal logarithmic differences. Since density is a logarithmic quantity equal density steps in the positive produce the desired logarithmic steps of image brightness on the screen. In order to produce these equal density steps in the positive the photographic reproduction characteristic requires equal density steps in the negative over a large part of the fade. A fade-out in which the density change follows this course has been found satisfactory.

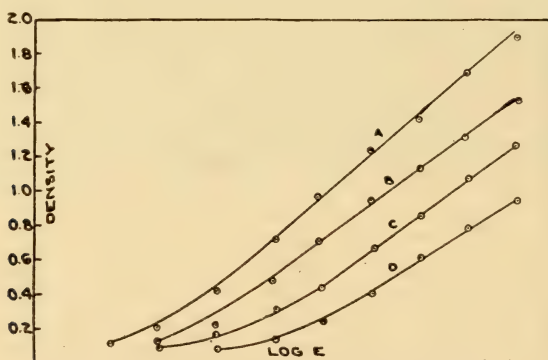


Fig. 1

Negative Fade-Outs

In order to make chemical fade-outs in a negative which are similar in appearance to those produced in the camera, a photographic reducing solution must be employed which has the property of altering the densities of the negative in such a way that it will appear underexposed instead of underdeveloped. The so-called cutting reducers are of this type and their action is illustrated by the curves in Figure 1. In this figure each curve represents the densities corresponding to a logarithmic series of exposures as is usual for photographic characteristic curves. Curve A shows the densities before treatment with the reducer, and Curves B, C and D the densities remaining after various degrees of reduction. As the time of treatment is increased, the lower densities are removed completely and all densities are lowered by an approximately equal amount which gives the desired appearance of underexposure. The data from which these curves were plotted were obtained by the use of a modified Belitzski reducer. (1.)

In Figure 2 are shown curves representing the change of density in a highlight which took place throughout the length of two camera fades selected at random from commercial productions. These curves show considerable differences and the departure from a linear change in density is rather wide. The change in highlight density with increasing distance from the start of the fade-out is slow at first and finally rises to an approximately constant rate. In view of the fact that a fade-out in which the highlight density changes at a uniform rate throughout the fade has been found to have a pleasing and perfectly normal appearance, it can be concluded that the particular shape of the curves in Figure 2 indicate inefficiencies and are merely the result of mechanical expediency.

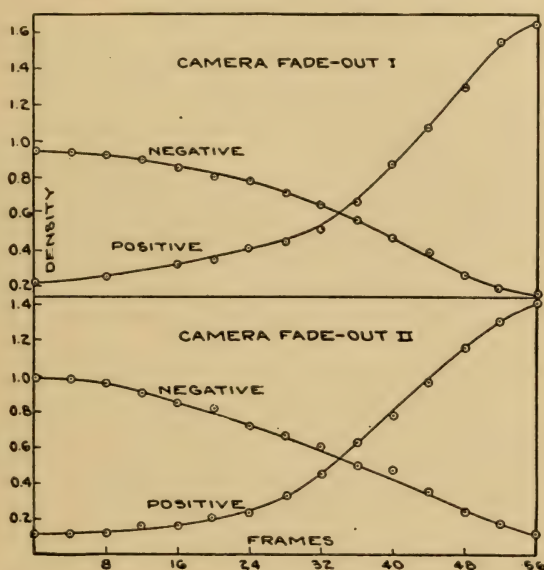


Fig. 2

Photographic Reducing Solutions for Producing Fade-outs.

In Figure 3 the progress of density reduction with time of treatment using the modified Belitzski reducer is shown for a highlight area in a negative where the original density was 0.9. The formula for this reducer is given below.

Modified Belitzski Reducer.

(Formula R-8).

Ferric alum	-	-	-	-	-	25.0	grams
Potassium citrate	-	-	-	-	-	75.0	grams
Sodium sulfite (anhydrous)	-	-	-	-	-	30.0	grams
Citric acid	-	-	-	-	-	20.0	grams
Sodium thiosulfate	-	-	-	-	-	200.0	grams
Water to	-	-	-	-	-	1.0	liter

The Belitzski reducer which is more stable is recommended in preference to Farmer's reducer.

Farmer's reducer, as commonly used by photographers, consists of a 10 per cent solution of hypo in which is dissolved enough potassium ferricyanide to cause the reduction to proceed at the desired rate. Alternatively a two-bath process is sometimes used which involves the use of a potassium ferricyanide solution of suitable strength for the first bath and an ordinary fixing bath for the second.

The two-bath Farmer's reducer can be kept for long periods of time, but its use is more complicated and control is difficult. When the two-bath formula is used, the time of treatment in the first bath is varied to give increasing degrees of reduction from one end of the fade to the other. All parts of the fade are then given the same time of treatment in the second bath.

The three reducers mentioned above leave a faint stain image which is not ordinarily objectionable. When a cutting reducer is required which leaves no stain image, the iodine-cyanide reducer is satisfactory but it has the disadvantage of being very poisonous. It consists of a solution of potassium cyanide to which a small quantity of iodine has been added.

Another method of producing a fade-out which is free from stain is to bleach the entire length of negative where the fade-out is to be made and then redevelop the image to varying degrees along the length to produce the densities required in the fade.

Either of the two bleach formulas given below is suitable for converting the silver image to one of silver chloride or bromide.

Ferricyanide-Bromide Bleach

(Formula T-10a)

Potassium ferricyanide	-	-	-	-	-	20.0 grams
Potassium bromide	-	-	-	-	-	5.0 grams
Water to	-	-	-	-	-	1.0 liter

Permanganate Bleach

(Formula S-6).

Stock Solution A

Potassium permanganate	-	-	-	-	-	5.3 grams
Water to	-	-	-	-	-	1.0 liter

Stock Solution B

Sodium chloride	-	-	-	-	-	75.0 grams
Sulfuric acid (concentrated)	-	-	-	-	-	16.0 c. c.
Water to	-	-	-	-	-	1.0 liter

For use, mix equal parts of A and B immediately before using. The mixed bath does not keep long.

The silver chloride image can then be redeveloped to the desired degree in a developer such as D-16 diluted to one-fourth strength after which the film is fixed in an ordinary fixing bath to remove the undeveloped silver halide.

Before redevelopment is attempted, the bleached image should be exposed to strong daylight but not sunlight. The result of the bleaching and redeveloping operation is equivalent to proportional reduction so that the camera fade is not simulated so closely.

The curve in Figure 3 shows that the diminution of the density of a highlight with the Belitzski formula is not strictly proportional to the time of treatment. The shape of this curve is such, however, as to suggest that if that portion of a negative where a fade-out is

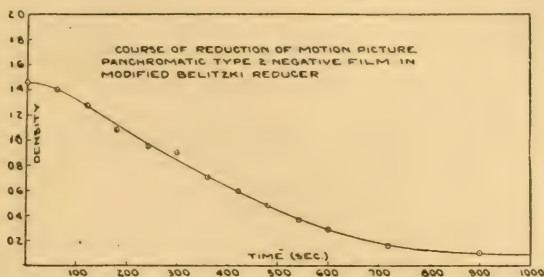


Fig. 3

to be made, were led, end first, at a constant rate into the reducer, a very acceptable fade-out would be produced. This opinion was based upon the similarity of the curve produced in this way and shown in Figure 4. Curve A shows the densities remaining in the highlight of a negative treated in this manner, and Curve B shows the highlight densities of a positive printed from it. A print including a fade-out made in this way was examined by projection and found very satisfactory and entirely typical.

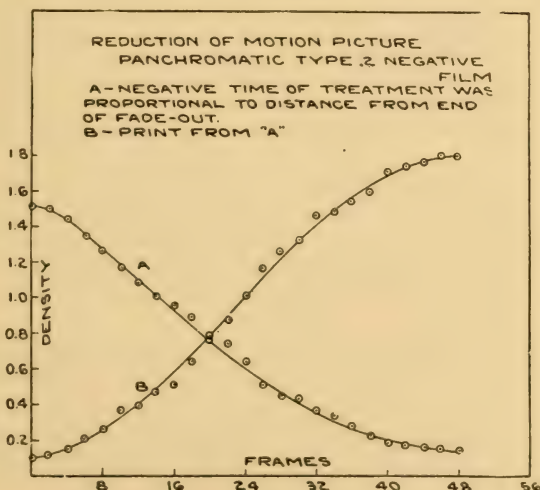


Fig. 4

. Methods and apparatus for handling the film during a treatment of this kind are discussed later in this paper.

Positive Fade-Outs.

It is assumed that a fade-out is to be introduced into an editorial positive print after it has been developed and when the editing is complete. A convenient method of darkening the film so as to simulate a fade-out is to stain the film with increasing quantities of a neutral black dye as the end of the scene is approached. A satisfactory method of controlling the density added in this way is to vary the time of bathing in an aqueous solution of a dye which has an affinity for gelatin.

No single dye having the desired properties was found but a combination of three dyes in the formula given below produced a visually neutral black with a projector low-intensity arc lamp. It would be possible to use these dyes in slightly modified proportion in case the spectral distribution of the light source used was somewhat different from that mentioned. The formula can be considered merely as a guide to the proper proportions because various samples of the same dyestuff are often found to differ in purity.

Visually Neutral Dye Bath

Acid anthracene brown B ²⁾	-	-	-	8.7 grams
Toluidine blue ³⁾	-	-	-	8.7 grams
Naphthol green ³⁾	-	-	-	2.6 grams
Water to	-	-	-	1.0 liter

In deciding upon the density to be added by dyeing, preliminary tests were made which showed that a maximum density of about 4.0 should be reached in order to obliterate the image entirely. This density seems rather high but is necessitated by the fact that the contrast is not degraded by the addition of a uniform density over the picture. It is necessary, therefore, to increase the superimposed density to a point where even the brightest part of the image is covered effectively. This condition is usually attained when the added density is 4.0 because of several factors. Among these, the following are important:

(a) Visual contrast perception is greatly reduced at a screen brightness level equal to one ten-thousandth of the ordinary level.

(b) The adaption level of the eye in an ordinary auditorium or theatre is usually at a level which is much higher than that which would give the best contrast perception when the fadeout is in progress.

(c) The stray light falling on the screen is usually enough to obliterate the image beyond a brightness level reached during the fade.

From the considerations cited previously it was concluded that a constant change in density with distance along the fade would be suitable. Tests of positive fades made in this way proved satisfactory on projection.

It was found that the density produced by the dye formula given above was proportional approximately to an exponential of the time

¹⁾ Grasselli.

²⁾ Hoechst (marketed by General Dyestuffs Corp., 233 Fifth Avenue, New York, N. Y.)

of bathing, as shown by the curve in Figure 5. In order to obtain, on each frame, a density which is directly proportional to the distance from the end of the fade it was necessary to vary the time of treatment throughout the length of the fade in a manner which is functionally related to the exponential rate of growth of density with time of treatment. A fadeout of this type, the curve of which is shown at A in Figure 6, was made by timing the dye treatment according to the indications of the curve in Figure 5, to give a constant rate of increase in density along the length.

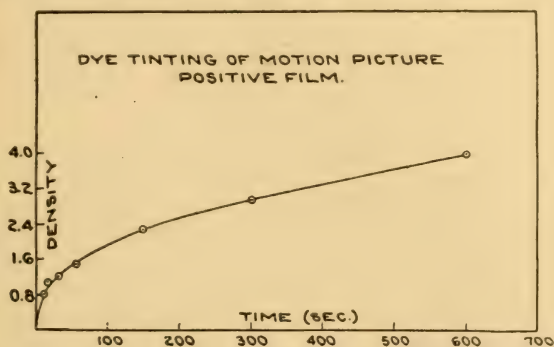


Fig. 5

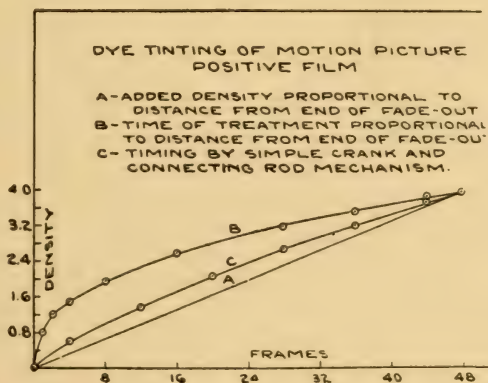


Fig. 6

Curve B in Figure 6 shows the densities produced by leading the film at a constant rate into the dye solution, a procedure which, as might be expected, gives very poor results.

Curve C in Figure 6 shows the densities which resulted from times of treatment which could be given by a simple crank and connecting rod mechanism. This fade-out was found quite satisfactory.

Methods of Handling the Film When Making Fades.

Of the numerous ways of causing a varying degree of chemical treatment from one end of the fade to the other, the simplest is to vary the time of treatment.

Dye Application

In the case of the application of a dye solution to the film the treatment can be carried out according to one of the methods for which instructions are given below:

(1) With the film strip lying, emulsion side up, on a flat surface, rub the surface lengthwise with a wad of cotton soaked with the dye solution. Start each stroke at the end which is to receive the lesser time of treatment. As each frame in succession receives its full time of treatment, blot it off and guard it from further contact with the cotton wad. As treatment is discontinued on one frame after another, the swabbing stroke is thereby shortened more and more. When the treatment of the whole strip is completed it should be free from spots of liquid and should not be washed but is ready for use when dried.

(2) If a large number of fades are to be made, it is preferable to treat several strips at a time by lowering them at a predetermined rate into a tank or tray containing the dye solution. That end of the strip which is to be bathed for the shortest time is immersed into the bath last. When the treatment is completed, draw the strips quickly from the bath, passing them through a squeegee to remove excess liquid from the surface. The fade is ready for use as soon as it is dry.

The equipment required for this operation depends upon the method of timing and may vary from a wooden rod with hooks, to which the various strips are attached, to a completely automatic machine by which the treatment is timed and the film withdrawn and squeegeed. The elaboration of the equipment will depend on the quantity of work to be done but perfectly satisfactory results can be obtained with the simplest equipment. Methods of automatically controlling the time of treatment are discussed below:

Treatment of the Negative

The mechanical handling of the negative during the treatment is essentially similar to that of the positive but certain limitations are imposed by the nature of the processes. Both reducing solutions and developers which are used in producing negative fade-outs act upon the image at a rate which is slower than the rate of diffusion from the solution into the gelatin. The consequence of this is that when the film is removed from the bath it contains a considerable quantity of unused solution which continue to work unless prevented by prompt action. The operation must be planned, therefore, in such a way that the treatment of all portions of the fade is completed simultaneously and provision must be made for quick removal to the next bath or the wash as the case may be. Usually the action continues to a slight extent in the subsequent bathing or washing but this can be minimized by adequate agitation of the film in the bath. At any rate, the further action can be made definite and uniform by proper handling and allowance can be made for it in the determination of the time of treatment.

The following procedure assures a satisfactory fade-out when the times of treatment have been determined properly for the existing conditions.

(1) The Belitzski, one-bath Farmer, or Iodine-Cyanide reducing solution should be placed in a tank or tray large enough to accommodate the full length of the fade-out. Lead the strip into the bath at a rate which will give to each frame time of treatment found necessary in previous trials. Allow the end which is to receive the least time of treatment to enter the bath last. Keep the liquid moving during use to assure uniformity of treatment. This is especially advisable in a shallow tray where natural circulation is very little.

When the treatment is complete, draw the strip quickly, preferably through a squeegee, and place it in running water. Agitate thoroughly during the first minute of the wash to remove the reducer uniformly.

(2) When the two-bath Farmer reducer is used, the treatment in the first bath is carried out as described under method No. 1 above. When the film is removed from this solution, it is placed in the second bath where it should be agitated for 1 minute and then allowed to remain for about 10 minutes.

(3) The following directions apply for the bleach and re-develop process. Bathe the whole fade-out in the bleaching solution for a time somewhat longer than that required to show the pale yellowish white color through the film support. When bleaching is complete remove the film and wash. (If the permanganate bleach has been used, the dark brown stain should be removed before washing by a short treatment with a 1 per cent solution of sodium bisulfite.) When washing is complete the fade-out is produced by lowering the film, end first, into an ordinary developing solution which may be diluted for convenience in timing.

The end of the fade-out which is to have the greatest density should enter the developer first. When all portions of the fade have received the proper times of development as determined in previous trials, the fade is removed quickly to an acid fixing bath where it is agitated for about 1 minute and then allowed to remain for 10 minutes. Fixation is followed by washing and drying after which the fade-out is ready to be spliced to the negative.

It is advisable, before any of the above operations on negatives are undertaken, to harden the gelatin by 5 minutes' treatment in the following hardening solution.

Hardening Solution (Formula SH-2)

Formalin (40% solution)	-	-	-	5.0 c. c.
Sodium carbonate (anhydrous)	-	-	-	5.0 grams
Water to	-	-	-	1.0 liter

If the negative has not been properly hardened, reticulation and frilling of the gelatin are liable to occur in the after process.

Timing the Treatment

Although it would appear that the motion of the treated strip of film should be stepwise so that all portions of a single frame receive the same treatment, this is not necessary. In a fade of the usual

length the change is so gradual that no variation in density from top to the bottom of the frame can be detected if the fade is produced by leading the film into the treating solution by a continuous instead of stepwise motion. This makes possible a wider choice of methods of timing.

If the handling is to be entirely manual, then the stepwise method is probably the best choice because of the difficulty of estimating the velocity in a continuous motion. It is recommended to adjust the concentration of the solution so that the process is complete in about 10 minutes.

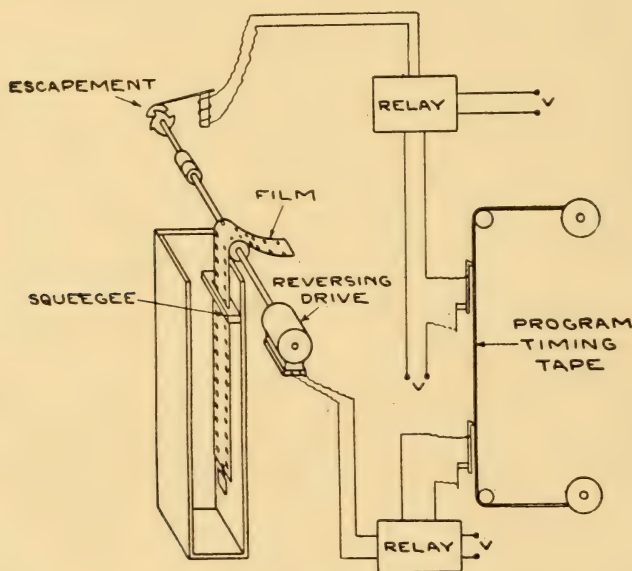


Fig. 7

Schematic Drawing of Machine for Making Fades with Tape for Program Timing

If the time of treatment is to vary directly as the length of film traversed, the film can be led into the bath either one frame at a time at equal time intervals or continuously by the use of any one of the common mechanical arrangements for producing motion at a constant rate. The use of mechanical timing means is very desirable even though a large part of the process is to be carried on manually.

If the time of treatment is not required to increase directly as the length of film, then a more complicated timing means must be chosen. As shown in Figure 5, for the dye treatment the relationship between time of treatment and length traversed in exponential, a relationship which is not attained precisely in a simple mechanical device. If the motion is controlled by the use of a cam of special shape the apparatus is somewhat expensive and usually awkward and difficult to alter for varying treatment.

A device described in a previous communication (2) may be used for the purpose because it can be adapted very easily to control the motion in any manner described. This device is illustrated schematically in Figure 7 with some of the other equipment which might be used for handling the film. The timing element proper consists of a tape moved at a constant rate under a set of small levers. Perforations made in the tape at the necessary points move the levers, making electrical contacts by which the film advancement ratchet can be moved, motors started, stopped, reversed, etc.

There are other devices commercially available for timing a predetermined sequence of events such as the blowing of time whistles, ringing bells, etc., which might be adapted to this purpose. As mentioned above, there is always the possibility that an approximation of the motion required which is much more readily attained will be equally satisfactory in practice.

In the construction of apparatus for the treatments described in this paper it is necessary to take into account the corrosive nature of the solutions when deciding upon the material to be used in contact with the bath or the wet film (3).

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- (2) Jones, L. A.: A New Non-Intermittent Sensito meter, *J. Frank Inst.* 189: 303, Nov. 3, 1920.
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Photographing a scene in "Transatlantic"

LIGHTING

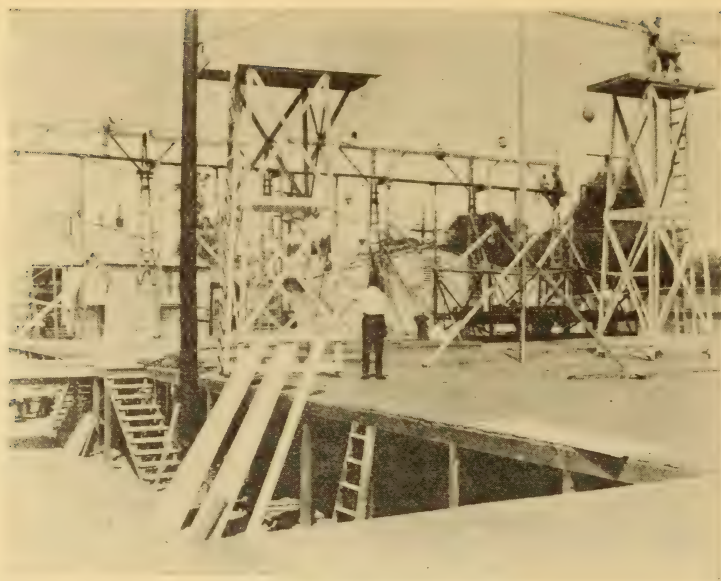
James Wong Howe

METHODS of lighting a motion picture set have changed tremendously since the day, long ago, when Cecil de Mille wrote that lighting to a motion picture was like music to an opera: but the importance of skillful lighting has not changed, save to increase. With the early films, lighting merely meant getting enough light upon the actors to permit photography; today it means laying a visual, emotional foundation upon which the director and players may build. In other words, lighting has changed from a purely physical problem to an artistic, or dramatic one.

The first moving pictures were made exclusively by daylight. The first studio—Edison's "Black Maria"—was made to utilize natural light. It was a small building, scarcely larger than an ordinary garage; actually, it measured about 20 by 25 feet. It was a mere framework, covered with tar-paper, with one end that could be opened to admit the sunlight. The whole studio was on a turntable, so that the stage could follow the sun! Another of its contemporaries—the first Vitagraph studio—was merely the top of a New York office-building, where, on sunny days, the troupe could erect their canvas scenery, and hurriedly shoot their scenes while the sun lasted. With this beginning, it is small wonder that when the first dramatic films arrived, and after stories began to demand more scenes than could be made actually out of doors, all studio stages were daylight affairs. At first they were merely large, flat platforms, upon which the sets could be built; then, as photographic skill grew, there were added increasingly intricate systems of muslin diffusing curtains overhead, worked by a network of cords, and by which the light could be somewhat controlled. And finally, as the movies began to change into a respectable, stable business, there came vast, steel-framed, glass walled stages.

About this time, cinematographers began to discover that they could get better results if they mixed a little artificial front light with the top light supplied by the sun. From this it was but a step (probably taken on a rainy day!) to the discovery that the top light could be supplied better by artificial means than by the sun. And from then on the daylight stages began to disappear, and the art—or science—of lighting came into being.

The tools used in lighting have developed slowly. At first the only lights—either for supplementary use, with daylight, or to take its place entirely—were the Cooper-Hewitt Mercury-vapor tubes. Then came arcs, first to supplement the softer "Coops", and eventually to take their place almost completely. One or two rarely adventurous souls experimented with incandescent bulbs, but, since the ortho film of those days was only weakly sensitive to the yellowish rays emitted by these lights, the bluer and more actinic arcs and Mercury tubes remained supreme.



An early open-air daylight stage.



D. W. Griffith, in 1920, making an interior for "Way Down East" by daylight, plus some overhead arcs.

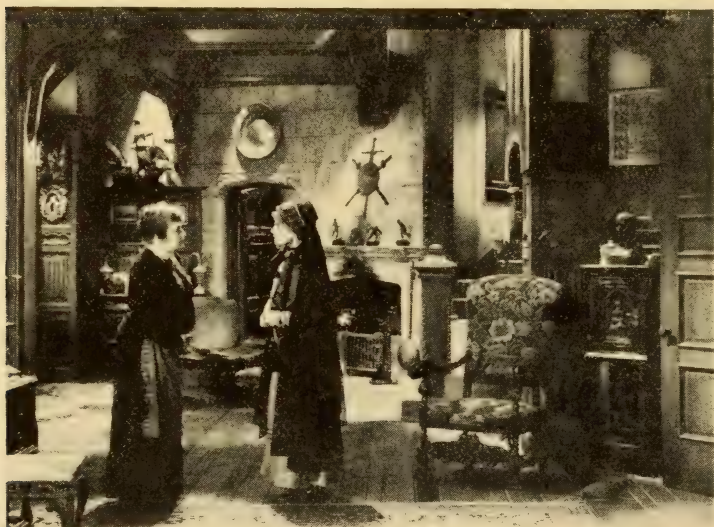


Cecil de Mille, in 1911, making "The Squaw Man" on an open stage in a Hollywood orchard. Note muslin diffusers overhead.



Making an exterior entirely by artificial light in 1931.

Eventually, two revolutionary technical developments made the incandescent light imperative. The first of these was the development of panchromatic film. In this type of film, the sensitivity is not only in the blue end of the spectrum, but extends far into the yellow and red. So it was soon found that inkie light was far more efficient with this film than was either the arc or the vapor tube. The second innovation, which followed close on the heels of the first, was sound. When the microphone appeared on the set, it demanded absolute silence—and the arcs sizzled and sputtered very loudly, while the Mazda bulb was, once it was warmed up, completely silent. Therefore, as sound pictures became the rule, the incandescent light became, perforce, universally accepted. This acceptance was given grudgingly,



The more pictorial the set, the easier it is for the cameraman to secure pictorial compositions and lightings.

but as time wore on, and we became more and more accustomed to using inkies, we found that they were, after all, a real improvement. Therefore, even now that the arc has been satisfactorily silenced, very few cinematographers have returned to their use. The superior tool has won out, aided, perhaps, by a surprising lethargy on the part of the arc makers, but principally because it is the tool best suited to modern conditions.

Today, although we are only at the beginning of the really scientific design of lighting equipment, we have a greater variety of lighting tools to hand than ever before. In the old days, aside from the Cooper-Hewitt banks, we had our choice of single and twin-arc broadsides, spotlights and baby spotlights, and two or three large

sun-arcs. Now, in addition to these (if we still care to use them), we have incandescent broadsides, overhead strips, "Lupes", Deitz floodlight banks, "sky lights", baby spots, regular spots, rifle spots, and big 18", 24", and 36" reflector semi-spots. In addition, we have an almost endless array of accessories for controlling the light: there are all sorts of diffusers—silks, gelatines, colored gelatines, ground-glass diffusers, florentine glass diffusers, spill-rings, and so on, to say nothing of frosted bulbs. Most recently, the new Fast "Special" and "Super Sensitive" emulsion, with their non-halation bases, have enabled us to use far less light than ever before, and to get better softer, more natural results.



An excellently handled, low-key exterior from "Devotion," photographed by Hal Mohr, A.S.C.

But no tool is any better than the manner in which it is used. And the high quality of present day photography certainly indicates that most cinematographers are using their equipment to good advantage.

It is easy enough to discuss the *equipment* used for lighting; it is easy enough to discuss the *effects* obtained: but it is almost an impossibility to really discuss the *methods* by which this equipment is made to yield the effects it does. For, to return to Mr. de Mille's analogy, lighting is like music: for with identically the same resources at hand, no two artists will work the same way, even though their results may in the end prove all but identical. So, too, cinematographic lighting has its Mozarts and its Wagners—its artists who specialize in light, delicate tones, and others who prefer the sweeping effect, the crashing *crescendo*. Obviously, each will have

his own way of working. Therefore, unless one is to go into a detailed analysis of the methods of a number of cinematographers, any discussion of lighting must be based largely upon one's individual technique.

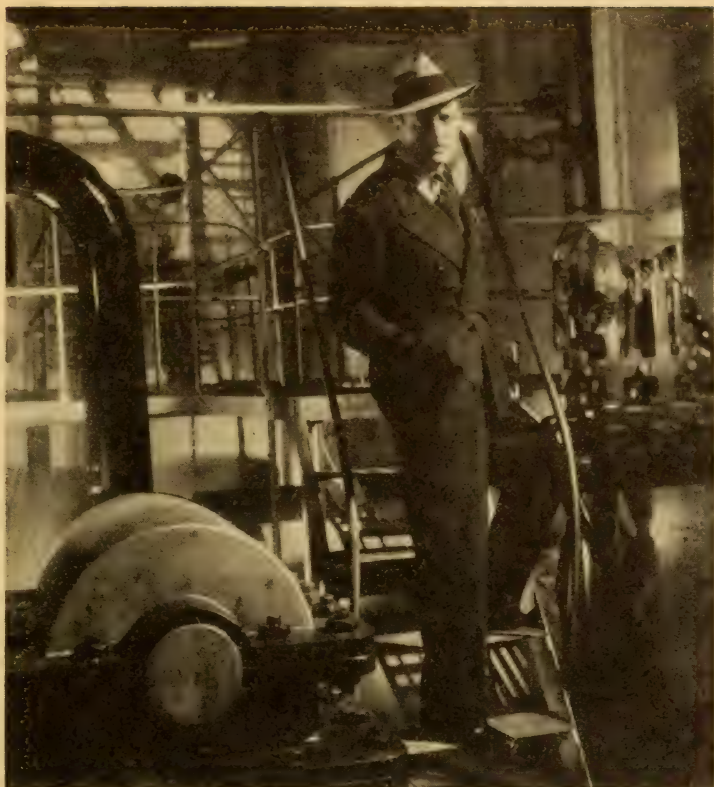
This, in turn, necessitates the intrusion of the personal pronoun. If I do a thing one way, it does not follow that it is what John Seitz, or Karl Struss, or George Barnes would do. It does not follow that



A good example of close-up lighting.

my way is the *only* way; it is simply the method that my experience and my personal inclinations suggest. In fact, although I might get a certain effect through one means, another cinematographer might use entirely different methods to gain the same end—and either of us would be quite at sea if we tried to ape the other's methods.

Personally, I have always felt that the problem of lighting is generally approached from the wrong angle. Instead of approaching any given set or action with the question, "How shall I light this?",



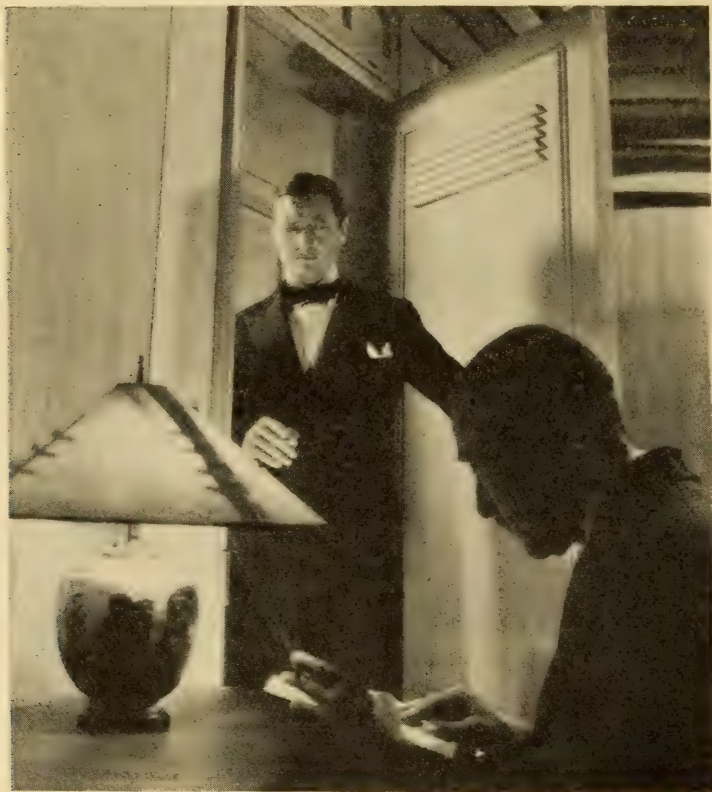
Even in surroundings such as above, virile compositions and lightings can be secured without objectionable contrast.



Perfect coordination of lights and composition are needed for weird effects.

I prefer to approach it with the thought of, "What compositions can I make with this set and this action?" Then I proceed to make those compositions—and the lighting automatically takes care of itself.

In figuring out the compositions of a scene (I say *compositions* advisedly, for as surely as your characters move around in the course of their action, so will you have more than one composition—and you must plan every move with regard to making and keeping the composition good)—in figuring out my compositions, I consider two factors: first, the possibilities offered by the set and the actors, and second, the possibilities offered by the action outlined in the script. In



It is not always necessary to fully light the faces of important characters.

using such a method, however, it is essential to have a sympathetic director—one who consciously and unconsciously realizes the importance of pictorial composition in every frame, and who is not averse to making occasional slight changes in his action in order to improve the visual quality of the scene. Some directors, unfortunately, feel, with Hamlet, that "the play's the thing"—and resolutely refuse to cooperate with the cinematographer in his efforts to aid the play with



Without resorting to excessive contrasts, the lighting of this scene serves to heighten the dramatic tensivity of the action.



Even when working in a higher key, lighting can be used to focus the attention of the audience, as it does here on the man at the left.

his photography. Others—like William K. Howard, for instance—realize that, despite the use of dialog, they are still working in a predominantly visual medium, and that anything that either they or the cinematographer can do to heighten the visual appeal of the picture is just so much to the good.

Every scene has its centre of interest. It may be the face of one actor, or of several; it may be merely a part of a face; it may be a hand or foot; it may even be some inanimate object—a letter, a pistol, a



Lighting aids in focusing attention on the presence of the woman in the background, and upon the key in the man's hand.

key, or a dropped handkerchief. Whatever it is, it is that feature which for the moment is most important in advancing the story. In any case, it is the key, not only to the dramatic situation, but to the photographic composition. If you build your composition upon that, and then build your lighting upon the composition, why—there's your picture!

In building up your lighting this way, you first light this salient point (or points). Get enough front and side light to give good

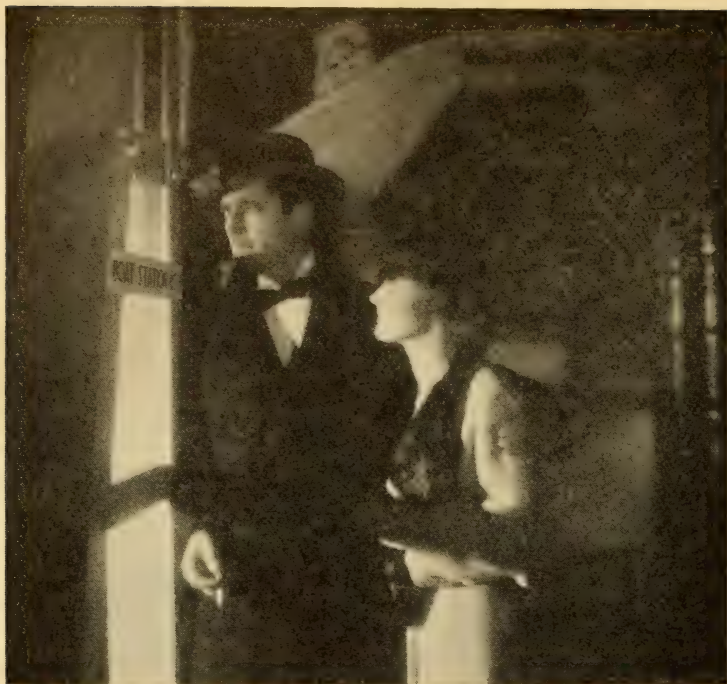
definition, and enough back and top light to give the necessary modelling. Then add enough light elsewhere in the picture to bring out such of the other details as you want, the way you want them brought out. Then check the whole carefully to see that the result is natural. In almost every instance there should be one definite source from which the light should appear to come. This gives



*The lighting serves as an essential part of the composition of this scene from
"Transatlantic"*

an illusion of reality, if it is not overdone; but it must be remembered that in most cases if we have the light all literally coming from one source, the effect will be both unpleasant and unnatural, for we will have no modelling, and exaggerated contrasts. Therefore, the thing to do is to have the light from our source of sufficiently greater intensity than our modelling and general light that it projects the illusion of reality without killing the general lighting which makes our exposure, or the modelling lighting which gives us the illusion of roundness.

Of course there are scores of little tricks of lighting which help to give the illusion of depth and actuality. Every photographer or



For night exteriors, "source" lighting may at times be more contrasty



Even in such a simple scene as this, lighting can serve to aid the composition

painter soon learns, for instance, the value of contrasted planes—different degrees of illumination between foreground, background, and middle-distance—and of little catch-lights on curved surfaces, archways, and draperies. Then, too, there is the fascinating field of securing roundness—to say nothing of dramatic effects—by the play of light and shade (not always, by any means, shadow) upon the figures and faces of people.

Low-key lightings have always been my favorites. These are generally used in melodrama and heavy drama, though they are occasionally utilized in melodramatic comedy-drama, as well. There are two principal methods of producing these effects: one may lay a foundation of soft, diffused light, and build up to the required highlights—or one may determine his highlights, and let the rest graduate down to the required shadows. Either method is good; personally, I prefer the latter, especially since the introduction of Fast Film. In the first place, by this means you can most easily obtain the heavy, velvety shadows so desirable in much of this work. In the second place, you need not use so much light, as, once you have arranged your highlights and modelling lights, the “spilled” light which leaks from even the best of equipment, will keep your shadows from becoming too unpleasantly empty. This is, of course, particularly true with the new film, which is so sensitive that the spilled light is often a serious problem.

And that is about all there is to say about the problem of lighting. Make your composition; arrange your primary lighting to accentuate whatever may be the salient points of that composition, arrange the rest of your lighting to properly display your set and players, keeping the tonal key of your picture as high or low as the mood of the story may require—and there you have your set lit! Add to this experience and an understanding and appreciation of the principles of visual art and photography, and you have the whole story. And, really, it may be condensed into the few words: lighting is not in itself an end, but a means to an end—composition.



Branches

Jackson J. Rose, A.S.C.

TRANSMISSION LOSSES IN MOTION PICTURE LENSES AND THEIR SIGNIFICANCE

J. F. Westerberg, A.S.C.

IT is well known that a portion of all light that enters a motion picture lens never reaches the film. A part of the light is lost by reflection at the various polished surfaces and a part is lost by absorption.

These losses are never consciously taken into consideration in practice as the effective speed of a lens is soon learned by actual trial. In view of the fact that the usual set of lenses on a camera are all of the same type and have been used for about the same length of time, no great differences in the transmission qualities are apt to be encountered.

Considered as a group, however, the lenses in the motion picture family have been found to vary sufficiently in some cases to be worthy of note. Potentially these differences may have some significance. Let us, therefore, look into the matter.

We may well ask ourselves the following questions:

- (1) How much light is actually lost in transmission by various lenses?
- (2) To what extent may the rated increase in speed of one lens over another be nullified by a difference in the transmission factor?
- (3) To what extent does the brightness of the image at a given stop vary in different motion picture lenses?
- (4) To what extent does the transmission factor of a lens influence its effective depth of focus in motion picture work?

Let us consider first how much light is lost in transmission by various lenses. Cheshire found that the transmission of visual rays could be approximately computed by allowing 5.22% for the loss by reflection at each glass to air surface and 2.4% for the loss by absorption for every 10 mm. of glass along the axis. This would make the loss due to reflection alone 27.5% for a lens having 6 glass to air surfaces and 35% for one having 8 glass to air surfaces.

Neblette, and also Clerc, in recent text books have made note of transmission measurements of various lenses made by Forch and Lehmann and other investigators. A well known F/3.5 lens is given a transmission rating of .600 indicating a loss of 40%. Greater losses are possible as is shown by the figure .387 for the transmission of an F/1.5 lens. This represents a loss of 61.3% of the incident light.

These data, however, are hardly sufficient for our purpose. Further photographic tests were therefore undertaken covering the motion picture lenses commonly used in this country and including those recently put on the market. Although not as exhaustive as might be desired, these tests should, however, give a reasonably true picture of

the comparative transmission qualities that one may encounter between lenses of various types and also between lenses of the same type, new and used. Under the circumstances, the names of the lenses cannot be divulged.

In making the first of these tests, eight brand new representative lenses were chosen, all having a focal length of 50 mm. These lenses were mounted on a block two inches thick and covering an area 8 x 10 inches. The under side of the block was the focusing plane and each lens was focused thereon at infinity. The block was then placed on an 8 x 10 super-sensitive panchromatic film. The exposure was made in the dark room. The film and the block were on the floor and a 25 watt frosted lamp was in the ceiling. A sheet of opal glass was placed two inches above the top of the block insuring equal illumination for each lens and a completely filled lens aperture, the importance of which has recently been shown by Rayton. The light was not confined to the vicinity of the axis but allowed to enter the lens over the whole angle of view. Several negatives were made of each test and the results averaged. Another sheet of the same film was exposed in an Eastman 11-b sensitometer in order to obtain a graduated scale of densities from which to construct the characteristic curve. All of the negatives were developed simultaneously to the same gamma. Density readings were obtained on an Eastman densitometer. The readings were all made at the center of each lens test, no attempt being made to measure the falling off in illumination away from the axis. The density readings were converted into relative exposures by reference to the characteristic curve.

In this sensitometric work Mr. Gordon Chambers of the Eastman Kodak Company rendered valuable aid and acknowledgment is hereby gratefully made.

Table I gives the results obtained in comparing eight typical lenses. Lens A an F/3.5 lens was arbitrarily used as a standard for purposes of comparison as its transmission factor of .600 had been previously determined and published.

TABLE I.
Relative Transmission.

Lens	Lenses set at F/4 or nearest stop mark and compensated to F/4	All lenses set at F/4 some by approxima- tion	Lenses set to balance exposure of lens at F/4	Average	Equivalent stops for equal exposure	Total trans- mission
A	1.00	1.00	1.00	1.00	F/4.00	.600
B	1.00	.96	1.08	1.00	F/4.00	.600
C	.83	.96	.86	.88	F/3.76	.528
D	.90	.84	.96	.90	F/3.80	.540
E	.89	.76	.84	.83	F/3.64	.498
F	.83	.91	.94	.89	F/3.79	.533
G	1.03	1.08	.96	1.02	F/4.04	.624
H	.69	.64	.65	.66	F/3.25	.396

Table II shows comparisons of old lenses with new ones of the same type. No scratches or oxidation of the glass was apparent in

any of these lenses. Although it would have been desirable to include many more lenses, the tendency of transmission losses to increase as a lens gets older seems to be unmistakably shown. Lenses showing greater losses than these could undoubtedly be found.

TABLE II.

Lens	Relative Transmission	Equivalent stops for equal exposure	Total Transmission
X-1 (new)	100.0	F/4.00	.600
X-2 (old)	92.2	F/3.85	.552
Y-1 (old)	77.7	F/3.52	.462
Z-1 (new)	85.3	F/3.70	.518
Z-2 (old)	79.5	F/3.57	.475
Z-3 (old)	67.4	F/3.29	.404

The indications are then, that the average lens on a camera has a transmission loss of about 50%. This loss may be as little as 40% in some types when new and a loss of over 60% may be expected in some types, especially after they have been in service for some time.

We are now ready for the second question.

To what extent may the rated increase in speed of one lens over another be nullified by a difference in the transmission factor?

The two lenses that were quoted afford one example.

TABLE III.

Lens	Stop used	Relative brightness of image (assumed)	Transmission Factor	Equivalent Stop	Relative brightness of image (actual)
F/3.5	F/3.5	1.00	.600	F/4.52	1.00
F/1.5	F/1.5	5.44	.387	F/2.41	3.52

In this particular case the F/1.5 lens instead of being about $5\frac{1}{2}$ times as fast as the F/3.5 lens is in reality only about $3\frac{1}{2}$ times as fast when both lenses are used at their full aperture. The net gain is therefore only 65% of the rated gain.

Among the lenses in Table I, it was found for example that the net gain of lens E over lens B was only $39\frac{1}{2}\%$ of the rated gain and in the case of lens C over Lens B the net gain was only 16% of the rated gain.

In all of the above cases the increase in aperture has been accompanied by the use of an additional uncemented lens element which has increased the number of reflecting surfaces by two. A curious situation is here created—that as the size of the maximum aperture is increased the percentage of net gain also increases. In other words, to attempt only a minor increase in aperture by means of an additional uncemented lens element does not seem to be worth while from a quantitative standpoint.

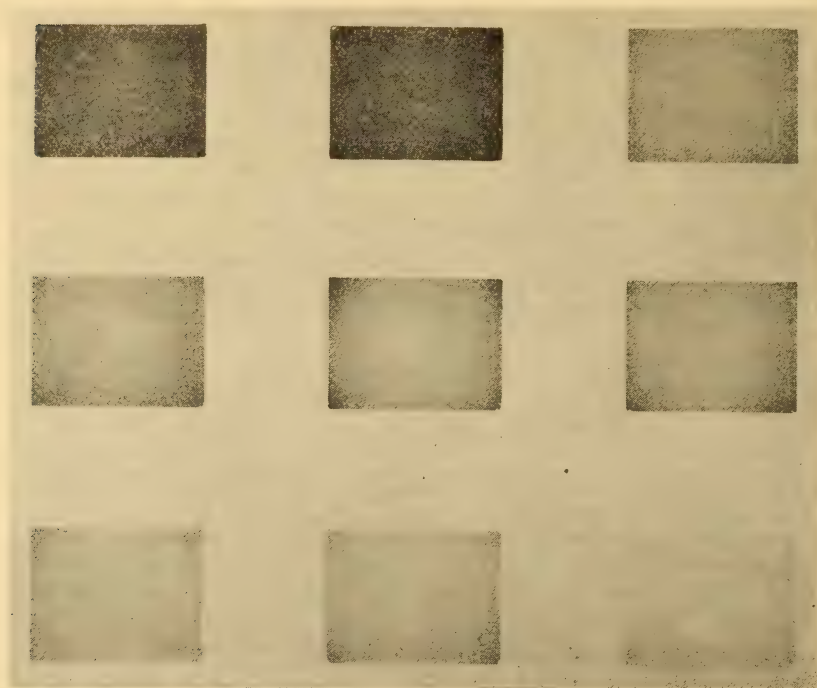
We now come to the question of how much the relative brightness of an image may vary at the same stop in various motion picture lenses.

Here quoted figures reveal the following:

PLATE IV

Lens	Stop used	Transmission Factor	Equivalent Stop	Relative Exposure
F/3.5	F/4.0	.600	5.16	1.00
F/1.5	F/4.0	.387	6.43	.64
F/1.5	F/3.21	.387	5.16	1.00

In this case the F/3.5 lens would give 54% more exposure than the F/1.5 lens at the same stop, a difference of over half a stop.



Print of a transmission test illustrating the relative exposure obtained by a group of lenses at their full aperture.

In addition to this our own data reveal that with the majority of lenses now in use the difference will usually never be greater than a quarter of a stop if the lenses are known to be in good condition but may easily exceed half a stop in the case of a new lens against a similar one that has been in service.

Now we come to the last question concerning the extent to which the transmission factor of a lens influences its effective depth of focus in motion picture work.

Here the relative brightness of the image at a given stop has more than usual significance in that the time of exposure cannot be increased to compensate for deficiencies in image brightness. In view of this,

the effective capacity of a lens in regard to depth of focus hinges in part on the relative brightness of the image that it is capable of producing at a given stop. We have seen that one particular lens may produce an image at $F/4$ equal in brightness to that produced by another at $F/3.2$. It is quite apparent that the lens operating at $F/4$ will produce an image having greater depth of focus without sacrifice of exposure. The same difference is possible between a new and a used lens. In the above case, the difference would amount to about 2 feet in total depth when focussed at 15 feet.

It can be seen from this that where the greatest possible depth of focus has to be obtained, the use of a lens with a relatively high transmission factor is indicated.

Now that we have looked over the situation, what may we conclude? Simply this, that an estimate of the capacity of a lens, an appraisal of its limitations as well as its possibilities, is not really complete until the transmission factor and its significance has been taken into consideration.

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Reflections

Elmer G. Dyer, A.S.C.

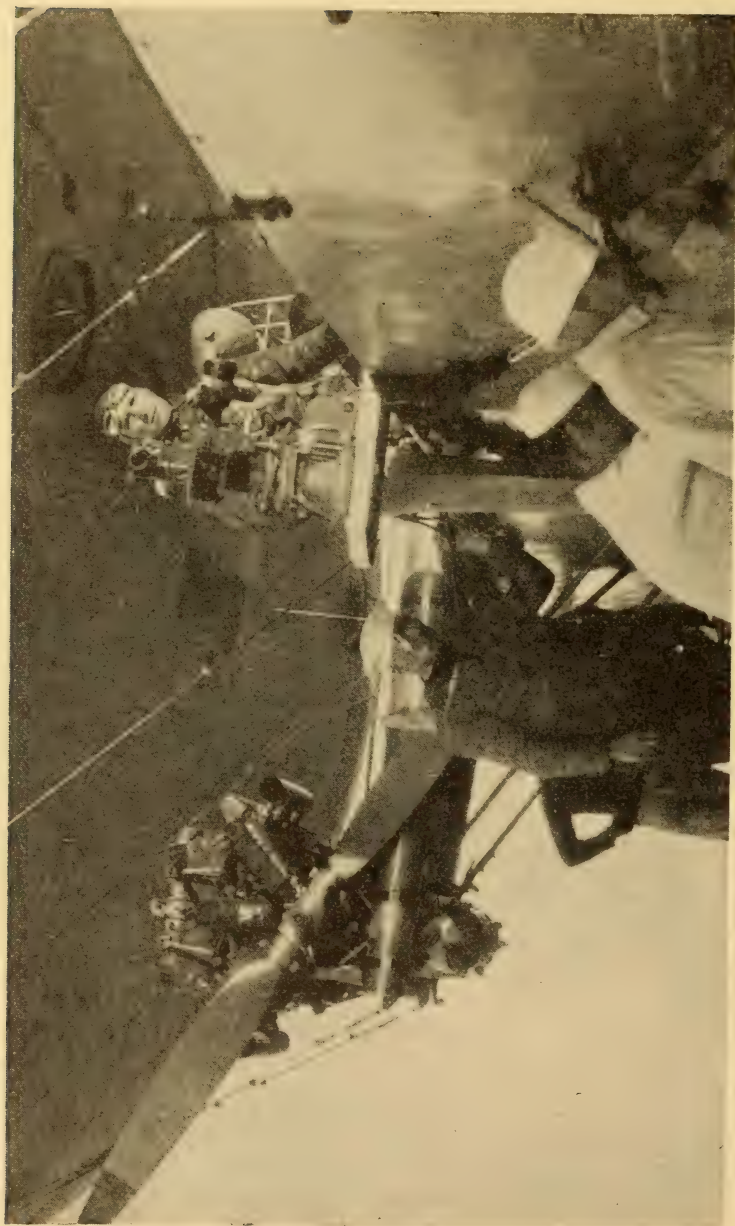
AERIAL CINEMATOGRAPHY

Elmer G. Dyer, A.S.C.

AS THE motion picture business has developed into a huge industry, it has demanded more and more specialization of its workers. This is particularly true of cinematography, for where, a few years ago, a cameraman had to be merely a good, all-around cinematographer, today the cameraman must be a specialist in some particular branch of the work. First cinematographers may specialize in dramatic or comedy photography exclusively; others specialize in process photography, or in miniatures; others in natural-color processes; and so on. But undoubtedly the most highly-specialized field of all is that of aerial cinematography. It is certainly a most exacting branch of our art, for, in addition to unusually stringent requirements in the way of purely photographic knowledge and ability, it demands unusual qualifications along physical, mental, and psychological lines as well.

The successful aerial cinematographer must, first of all, be an expert cinematographer. He must know photography in both theory and practice so perfectly that it is second nature to him: things happen so suddenly in the air that every fraction of a second counts; there can be no pauses for debating (mentally or otherwise) how to solve the particular problem in hand. Secondly, and of equal importance, the aerial cameraman must be physically, mentally, and psychologically fit. He must have the basic qualities of a first class stunt aviator: he must be physically fit, mentally alert, and equipped with unshakable nerves. He must have good eyesight, perfect equilibrium, and supernormal judgment of distance. Thirdly, he must know aviation. He must know airplanes, how each is constructed, and how each will perform. He must know pilots, and their capabilities. But more than anything else, he must know aerial photography, which is entirely different from earth-bound photography. He must know the results of every conceivable atmospheric condition upon his camera itself, as well as upon his picture—and how to so expose and filter as to master every one of them. Above all else, he must have an inborn talent for aerial photography—an indescribable knack of doing the right thing at the right time; not merely at the right minute, but at the right fraction of the right second.

The mechanical details of aero camerawork are relatively simple. The most important of them is the mounting of the camera. This varies, not only with the type of plane used, but with the type of scene being photographed. In any kind of cinematography, it is essential that the camera be so mounted as to be free from vibration; in aerial cinematography, this is doubly vital. The chief source of vibration, naturally, is the engine, although under some aerobatic conditions—such as steep power dives—other structural parts of the plane may likewise contribute some small amount of vibration. As engines go, aero engines are relatively low-speed affairs; they seldom



Mr. Dyer in one of the U. S. Navy's "J" lighter-than air ships. Note how his camera is fastened, and his own precarious perch.

(except in racing craft), deliver more than 2,000 R.P.M., whereas automobile engines may sometimes double this figure. Such slow speeds are a great advantage to the engine-builder, but they are a considerable hindrance to the flying photographer, for the vibration is far more pronounced at low speeds. Furthermore, each individual engine installation has its own peculiar period of maximum vibration. One engine may run as smoothly as could be desired at 1,850 R.P.M. and vibrate horribly at, say, 1,750 R.P.M.; another of the same design, in an apparently identical machine, might vibrate at entirely different speeds. Therefore, the flying cameraman must know each individual plane and power-plant with which he is to fly. But, to return to photography, the camera must be mounted so as to reduce this vibration to the minimum. In open machines, the mounting is usually a special fitting: a sort of saddle which is clamped tightly about the fuselage, just behind the rear cockpit. It is well to design this so that the mount and plane are insulated from each other by sponge-rubber insulators. Some of these installations have the camera rigidly fixed in place at the side of the ship, or directly in the centre; others have mounted the camera on a sliding track which may extend completely around the cockpit, or around the rear half only. In either case, of course, the camera itself is mounted on the usual gyro or friction pan-and-tilt tripod head, which, with the legs removed, is affixed to the mount. When government planes are used, the camera can at times be affixed to the regular Scarff machine-gun mount, which may be raised or lowered to any position, and which rotates freely around the cockpit.

In closed planes, the camera is, of course, placed within the cabin. Sometimes it can be used on a regular tripod, or a baby tripod, which is, of course, firmly chained down to the floor. At other times, some sort of a special mounting may be preferable. In one such installation that I have made, and used on several pictures, using a standard Buhl "Airsedan", I have used a mount in which the camera slid on a little track, so that it could be used inside the plane, or, if necessary, slid outside, and, by means of the panoramic tripod-head, trained forward or backward, as might be needed. In all cases where a closed machine is used, it is necessary either that one of the windows be opened (if this is possible), or that one of the doors be taken off.

It is difficult to say which type of plane is more suitable; both the open and closed models have distinct advantages. The closed jobs, naturally, are more comfortable. In them, you are protected from the elements—a very important factor in case you must fly long distances across country before reaching your destination, and in high altitude work, where you must face bitter cold at all seasons. Furthermore, you are protected from the powerful wash of air thrown back by the propeller. In a fast machine, this wash, or slip stream, is so powerful that you can hardly stand or move against it. Naturally, too, in a closed ship you are not so likely to be covered with oil thrown off by the motor: and even the best motors throw more or less oil, especially in types where the rocker-arms are not tightly covered.

In open planes, on the other hand, the visibility is immeasurably better than is possible in even the best of closed machines. One must work, however, in the open, and in considerable physical discomfort, due to the effects of the slip-stream, and to the almost inevitable stream of oil-particles thrown off by the motor. But from the rear cockpit of an open plane, visibility is almost perfect—save at a few angles which are inconsequential from the photographic viewpoint. All photography must, of course, be done from the rear seat; pilots seldom like this, as it is harder to fly accurately from in front, but it must be done in spite of their protests. And I must say here, most of the pilots with whom I have worked—and among them have been most of the outstanding Army, Navy, Marine Corps, and Civilian flyers—as soon as they learn just what problems a cameraman is facing, and what is to be done, are very glad to cooperate in every way.

For photographing aerial stunts of all kinds, the open plane is imperative, for maximum angle of view for the camera is mandatory. Furthermore, there is always a very large element of danger in this sort of work—particularly from collision—and the open machine is naturally far safer than the closed one. It is very difficult to escape from a small cabin, the door of which is almost completely blocked by cameras—especially when you are encumbered with heavy flying clothes and a parachute. The terrible accident of a year ago, in which two cabin planes collided, and carried to their deaths two pilots, a famous director, and ten cameramen, is still fresh in all our minds: had open planes been used, these fatalities could in all probability have been prevented.

Certain of the large, twin-motored planes used by the military services offer ideal conditions for aerial camerawork. In such machines as the Martin, Keystone, Fokker, and Douglas Bombers and attack planes used by the Army, and the Martin, Douglas, and Consolidated patrol seaplanes and flying boats used by the Navy, the motors are mounted outboard, leaving the fuselage free from the blast from the propellers; the cameraman may use either of the gunners' cockpits, one of which is located in the nose, giving perfect visibility at all angles forward and to the sides, and the other of which is in the conventional position toward the rear of the fuselage.

In any event, the camera should be motor-driven. It is often advisable, also, to mount two cameras side by side on the same mount, thereby getting either two identical negatives of the scene, or, by means of lenses of different foci, getting a long-shot and a closer shot of the action at one "take". I have used standard Bell & Howell and Mitchell studio cameras, as well as the Akeley camera in aerial work. The studio cameras have the advantage of greater film capacity, but the Akeley, having been designed expressly for accurate and facile operation under unusual conditions, is rather better suited to air work, and especially to photographing aerobatic flying from an open plane.

Panchromatic film is, of course, the obvious choice for aerial work, since so much depends upon filtering and color-separation. When

the new "Fast Films" were introduced, I was eager to try them in the air, for their improved color sensitivity would be of great benefit in my work; on the other hand, I realized that their tendency toward extreme softness of gradation, which is a great advantage in most camerawork, might well prove a handicap in aero photography, for here a healthy, almost exaggerated contrast is necessary. Then hard upon the heels of this first innovation came the announcement of the "Grey Base," non-halation variety of "Fast Film." This has proved to be the greatest forward step in years, in so far as the flying photographer is concerned. One would hardly expect to be bothered by halation in aerial work; but my first trials with the

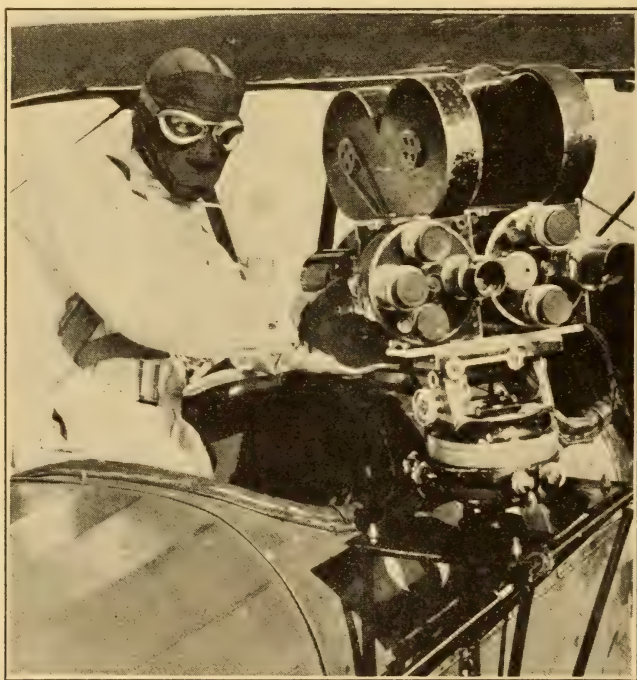


Mr. Dyer in an airplane, showing camera mounting

"Grey Base" emulsions showed that such had been the case. Apparently the terrific intensity of the light up there is sufficient to produce just such an effect—but uniformly distributed all over the film, rather than concentrated at a single spot. At any rate, the non-halation stocks seem to remove a veil that has always hung over aerial scenes heretofore. It is uncanny how this feature—which one would normally pronounce to be of less value to the flying cameraman than to his fellows on the ground—cleans and brightens up the picture. Now that it is so generally available, "Grey Base" stock should invariably be used for aerial cinematography.

The filters used in this work depend entirely upon the conditions encountered, upon the type of picture required, and upon the experience and judgment of the cinematographer. One may stock as large or as small a battery of filters as one cares to; it is certain that they will all prove useful at some time or other. Personally, I have found the following five to be the most useful; they should form the nucleus of any assortment. They are: the Aero No. 1; the Aero No. 1½; the G; the E-22; and the No. 72. Of them, the E-22

is by far the most useful, all around filter. It is much like the more familiar G filter, but of a deeper, more red-orange hue. It is, unfortunately, a very unstable filter, which fades and discolors very quickly; therefore, as a matter of safety, I use a fresh filter on each job. The E-22 will give, under most circumstances, just the proper degree of correction, and will match up well with scenes made on the ground with the G filter, so commonly used (especially with the new film) for exteriors. The Aero filters are particularly useful for scenes of the ground taken from the air; they were designed for just this purpose—that of cutting through the ever-present aerial haze. The G filter is another excellent general purpose filter. The No. 72 is a deep red screen, and is used for making night effect scenes by daylight.



Another illustration showing unusual camera mount for aerial photography.

In most production work, naturally, a more extensive assortment of filters will be necessary, not only to cope with special conditions, but to enable the aerial cameraman to match his scenes with those made on the ground for the rest of the picture.

Among the rare, special instances where unusual filters are required is that of photographing action on the ocean from the air. This

is comparatively rare in studio production, though it is fairly frequent in commercial and newsreel work. In order to properly render the greenish hue of the ocean, and at the same time avoid over or under correction in the sky, and to get a distinct division between sea and sky at the horizon, it is necessary to use a filter that has a certain amount of green in it; not, of course a pure green filter—such as the B, which would merely make the water go black—but a yellow filter with a slight greenish tinge. There are quite a few such filters; but as the conditions met with in such shots are in-

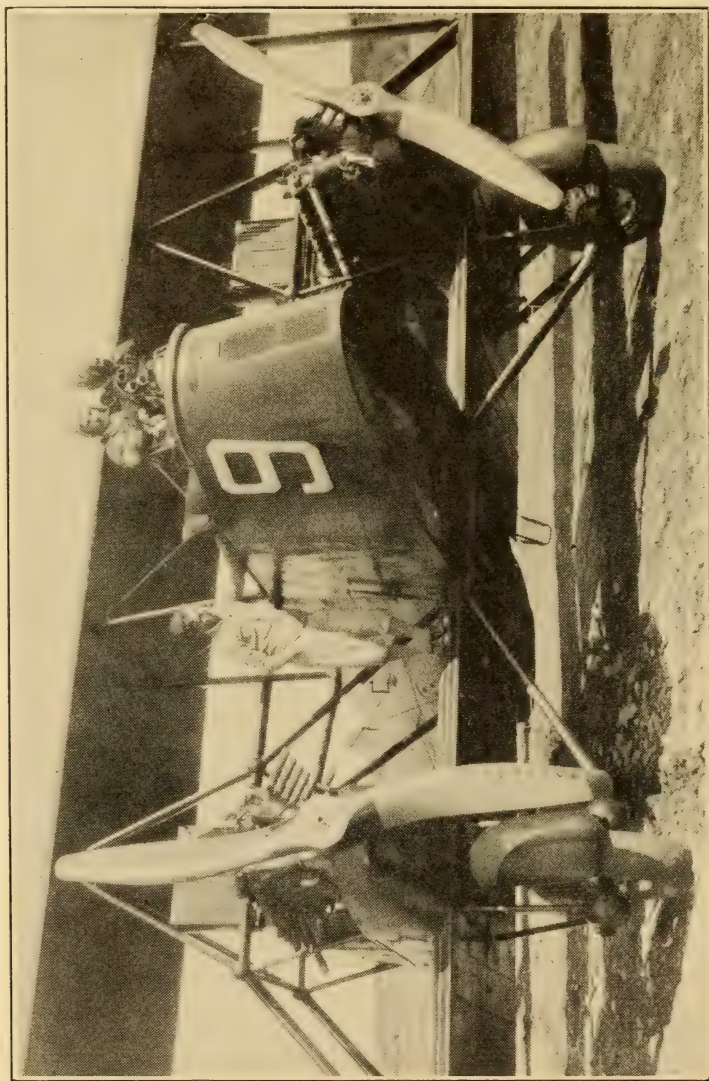


Here is an aerial cinematographer caught in action. Note how camera is mounted to give ease of operation.

finitely varying (I have found, through sad experience, that in this sort of work a filter may be perfectly satisfactory one day, utterly unsuitable the next, due to the chromatic changeability of the ocean) it would be unfair to recommend any one filter for this use; the only possible method is to make tests before every flight.

Exposure is another matter that cannot be governed by rule. Each flight—each scene—is an individual problem, and must be so recognized. Atmospheric conditions vary, not only between place and place, but between hour and hour. Therefore, experience is the only guide, or, lacking this, tests. But it is well to remember that as the altitude increases, the exposure must be cut down even more rapidly than in ascending to equal altitudes on land, as in the mountains.

Another disturbing factor in the exposure problem is that of vibration. If you reduce your shutter aperture too much, you will sooner or later reach a point where the shutter is in synchronism with the vibration period of the engine. This varies, naturally, in every case, being different not only in different planes and engines, but in different cameras. On the other hand, if you control your



Harry Perry, A.S.C., another famous aerial cinematographer with his equipment, ready to take to the air.

exposure only with the lens stops, you will find that at certain extremely small apertures *the subnormal diaphragm opening will alter the qualities of the filter used!*

The choice of lenses is another problem. Every photographer naturally has his own favorite objectives. And when you see two equally good cinematographers producing pictures of equal merit with different lenses—each of which is, according to the user of the other lens, an utterly worthless piece of glass—you realize that you cannot arbitrarily say "This lens should be used!" It can, how-



Mr. Dyer with his camera mounted on a U. S. Navy "J" Ship

ever, positively be said that, for aerial work, the shorter focal lengths are invariably the best, as the larger lenses, while magnifying the picture, likewise magnify the vibration of the plane. The only excuse for their use is in cases where the shorter focus lenses would necessitate dangerously close flying.

Whatever lens and camera equipment is used, however, the finder used should be of the type that gives a large, erect image. This is true even when the Akeley camera, with its unique matched-lens finder arrangement, is used; you cannot always keep your eye glued to the eyepiece of a camera when your plane is gyrating wildly to keep some looping, spinning stunt plane in range.

The lighting of aerial shots is comparatively simple. You can merely take the light as Nature supplies it; you cannot carry reflectors, diffusers, or booster lights into the air. The old axiom of

earth-bound photography, "when in doubt—cross your light," holds good in the air, as well. And, as in ordinary photography, the lighting must depend upon the mood and nature of the sequence being photographed. An example of this occurred recently during some aerial scenes that I made for Pathe's "The Suicide Fleet." One scene was of a column of battleships steaming along in formation: it required bold treatment, to emphasize the ponderous might of the fleet. Therefore, I had the plane maneuvered until I got a beautiful back-light on the ships, so that they were silhouetted against the



A practical head and face covering for the aerial cinematographer.

shimmering surface of the sea. As I flew down the long column, these massive black shadows against the shimmering background made a scene that was most impressive. In the same picture, I had to photograph from the air an old-time clipper ship, and to show its romantic beauty. Therefore I got it with a light that was just the least bit removed from a straight front-light. Then I had the pilot (I was in a Navy Douglas twin-motored seaplane) fly very low—ten or fifteen feet above the water—and approach the clipper on a straight line, from a point several miles off. To his credit, be it said that he followed the instructions to the letter, keeping the plane perfectly straight and level until we were almost upon the ship, and then edging off just sufficiently to miss it; I hardly needed to watch my finder.

All of these various factors which have been discussed—equipment, film, filters, and lighting—must all be dependent upon the nature of the scene being made. What may be exactly the right treatment for one type of shot may be exactly the wrong thing for

another one. In general, aerial scenes may be divided into three classes: Scenes of planes in the air; scenes of ground action or locations made from the air; and process backgrounds. The first two require no explanation; the third is that type of scene which is photographed to make, by the aid of process photography, a moving background for foreground action made in the studio. Such process scenes are made for several reasons: first of all, it is a vastly more satisfactory method of getting close shots of actors playing the roles of aviators, in sequences where they are supposed to be flying. Such



Another view of a "J" ship about to leave the ground with Mr. Dyer.

scenes can be made better this way, both photographically and dramatically, as everything can be controlled by the cameraman and director. Furthermore, even though many actors and actresses are good pilots, they are seldom accomplished stunt pilots, so this method is vastly more effective—and safer. Lastly, this method allows the use of dialog in such sequences—an illogical idea, of course, as any flying man knows, but one which is often dramatically necessary.

The making of these process background shots—"plates" or "keys," they are sometimes called—is a rather difficult business. The placement of the camera must be exactly right, so that the angle of the background is such as to make the illusion real. Then the exposure and filtering must be done with extreme accuracy, and understanding of the requirements of the process, or the shot will not be satisfactory.

At times, however, scenes are actually made in the air, with minor actors who are expert fliers, or with the few stars who are aeronautically—as well as histrionically—competent. In these scenes, the actor flies the ship, and a camera is placed at the proper place to get whatever angle is desired. It is motor-driven, of course, so the pilot-actor takes off, reaches the proper position, and presses the

starting-button of the motor (which is in the cockpit, at some distance from the camera). Then he acts, directs, and photographs himself—to say nothing of flying the plane himself. This method, however, is not so satisfactory from the director's point of view—and it certainly isn't from the cameraman's. Despite all the test flights you may make, you cannot be sure that the atmospheric conditions will remain the same, or that your actor-pilot will remember that he is for the moment his own cameraman as well, and fly the ship so that the lighting, etc., is as it should be.

In any sort of production cinematography it is a great advantage to work with a director who has a real knowledge of camerawork. Similarly, in aerial cinematography, it is an even greater advantage to work with a director who knows flying. Fortunately, most of the directors of air stories are pilots; William Wellman, Tay Garnett, Clarence Brown, Howard Hughes, Cecil de Mille, and many other outstanding directors are licensed pilots. It is well, too, to work with pilots who either have some knowledge of photography, or who at least have worked long enough in pictures to become camera wise—as are such men as Dick Grace, Frank Clarke, Frank Tomick, Art Goebel, or Bob Blair. But more than anything else, it is important to work with a pilot in whom you can place your entire confidence. You cannot do good work if you are worrying about your pilot's ability. If you are a pilot yourself, as was the late Alvin Knechtel, A. S. C., who would often maneuver the camera-ship into position himself, and then turn it over to the pilot, well and good. But better by far not to be a pilot, if being one makes you a worried, back-seat driver. In fact, if one could sum up the entire secret of aerial cinematography in a single sentence, it would be, *"Know your stuff; trust your pilot to know his—then both of you hop off and do your stuff!"*

A METHOD FOR TESTING A PHOTOGRAPHIC LENS

*Dr. W. B. Rayton, A. S. C.**

IT IS possibly no more difficult to design a photographic objective than it is to determine completely and accurately the value of the result. It seems obvious that since photographic lenses are designed as instruments for photography it should be a simple matter to take a picture with a lens and thus learn completely and almost without effort all about the ability of that lens to make a picture. This seems reasonable until the process is analyzed whereupon the photograph will be discovered to be not only a test of the lens but also something of a test of the camera, of the photographic emulsion, and of the technique of the photographer and the laboratory man. Since most people fail to derive much mental satisfaction from the contemplation of a negative, the process usually involves making a print also and in motion picture practice this positive print is projected on a screen entailing another series of variable factors all of which affect the degree of excellence of the final result.

There is another way in which lenses may be tested. By means of equipment known generally as a lens bench the magnitude of the residual aberrations in a lens can be measured. The information given by the lens bench is useful to the lens designer and it permits some attempt at quantitative specification of performance but it is practically impossible for the imagination to transform lens bench measurements into a mental picture of the quality of the image the lens can form. Lens bench tests can prove whether two lenses are alike or not. If they appear alike in every aspect they will undoubtedly perform alike in practice under the same conditions but if they are recognizably unlike under the lens bench tests it is generally impossible to determine what effect the recognized differences will have on the image quality of the lens without resorting to photographic tests.

The situation, therefore, is not all that could be desired even by one who has occasion to make comparative tests of lenses for his own information only and it is much more difficult for any agency such as a testing laboratory, for example, to find means for accurately and completely determining and expressing lens performance.

In the testing of any commodity there is apt to be a slight degree of suspicion on the part of the practical man concerning laboratory methods, a suspicion which like all others is founded on ignorance. It is manifested by the farmer in connection with the Department of Agriculture's tests of agricultural products and by the manufacturer

* Director of Scientific Bureau, Bausch and Lomb Optical Company

in connection with Bureau of Standards' tests. The so-called practical methods of test are "practical" sometimes because they are more rapid but sometimes, unfortunately, only because they are familiar. Laboratory methods are characterized by an effort to exclude extraneous influences to the end that only that quality of the commodity is tested concerning which information is desired.

In the realm of lens testing we might regard the making of actual pictures as the practical method and the lens bench examination as the laboratory method of testing. Objections to each have been suggested above. There is a method of procedure, however, that avoids to a high degree the misleading results obtainable by the ordinary photographic practice and at the same time escapes the uncertainties of interpretation encountered in considering the results of lens bench measurements. This method, although it may be considered a laboratory method, is a photographic one, but taking advantage of the conjugate relation between object and image planes, the photographs are taken in the plane ordinarily occupied by the object while the test occupies the plane of the ordinary image.

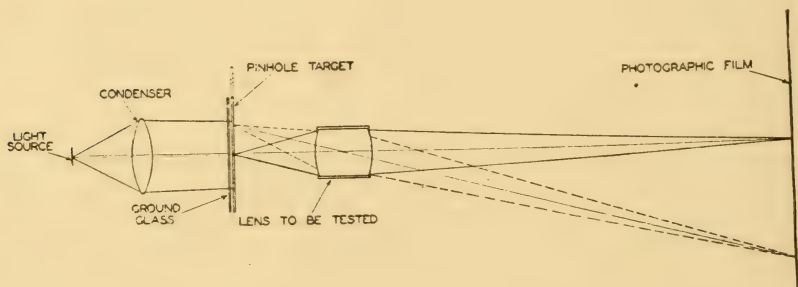


Fig. 1. Diagram of a proposed arrangement for testing photographic lenses.

Figure 1 shows in a schematic way the arrangement we have used. At the left is a source of light which may be an ordinary incandescent lamp or any other source desired. A condenser lens is employed to concentrate some of the light from the source into a reasonably parallel or converging beam. It is not important whether it be parallel or converging and in fact it is more of a convenience than a necessity for it is followed by a sheet of ground or "opal" glass to diffuse the light and to insure that the full aperture of the lens under test is employed. Immediately following the ground glass is a metal plate with a hole bored in it, mounted on a carriage which permits transverse movement measurable with a scale. For this arrangement a single plate with several holes in it can be substituted. If the spacing of these holes is chosen wisely no shift of the plate would be necessary and the test somewhat facilitated. The lens under test must be mounted perpendicular to the test plate and adjusted for focus until the hole in the test plate is imaged at the chosen distance on the image plane, the film plane shown at the right of drawing. In this arrange-

ment the photographic lens functions like an ordinary projection lens with the single but important difference that a plate of diffusing material is used between light source and object in order to avoid the danger of drawing false conclusions due to an incompletely filled lens aperture. This necessary condition has often been neglected in similar tests in the past and it cannot be too strongly emphasized here.

With this arrangement completed the test is conducted by taking separate and consecutive photographs of the hole in the test plate, setting it first on the axis of the lens and subsequently moving it at right angles to the axis in steps of any desired amount until a distance has been reached equal to half the length of the diagonal of the picture the lens is required to cover. After the focusing has been perfected with the hole in the center of the field the focus adjustment is not touched during the complete test. In the case of motion pictures the length of the diagonal is 28.65 mm. In carrying out the test the time of exposure will have to be increased as the hole is moved farther from the central position for reasons connected with the construction of the lens to some extent, with character of the performance of the lens and, more than anything else, with the character of the illumination. The difference in time of exposure thus observed is of practically no significance in reaching conclusions as to the performance of the lens. It should be self-evident that the image of the hole in the test plate will travel transversely as the test plate is moved going in the opposite direction and by an amount equal to the shift of the test plate multiplied by the magnification of the lens. This requires, therefore, that means be provided for moving the plate or film holder in a plane exactly perpendicular to the lens axis in order to make the various exposures.

The advantage of this test lies in the fact that all the aberrations of the lens manifest themselves on such a magnified scale that their effects are very large in comparison with the size of the grain of any photographic emulsion. If we choose a projection distance equal to a hundred and one times the focal length of the lens measuring from the front of the lens the magnification will be one hundred times. Interchanging object and image, that is reverting to the usual order, the reduction would be one hundred times or the magnification would be $1/100\times$. The ratio between the two magnifications will be 10,000. The effect of residual aberration will therefore be many times as great (but not 10,000 times) in the proposed procedure as in the ordinary use of the lens.

Any kind of photographic material desired may be used and the color of the light may be made anything from blue to red by means of suitable filters placed between the light source and the test plate.

The chart reproduced herewith, Fig. 2, shows the results of a test carried out in this manner with a 50 mm. Raytar lens at full aperture ($f:2.3$) together with tests of four other well known types of lenses of the same focal length and approximately the same relative aperture. Differences in lens performance are detectable in the original prints with an ease and certainty unapproachable by the ordinary

Projection Test Plates of 2-Inch Picture Camera Objectives

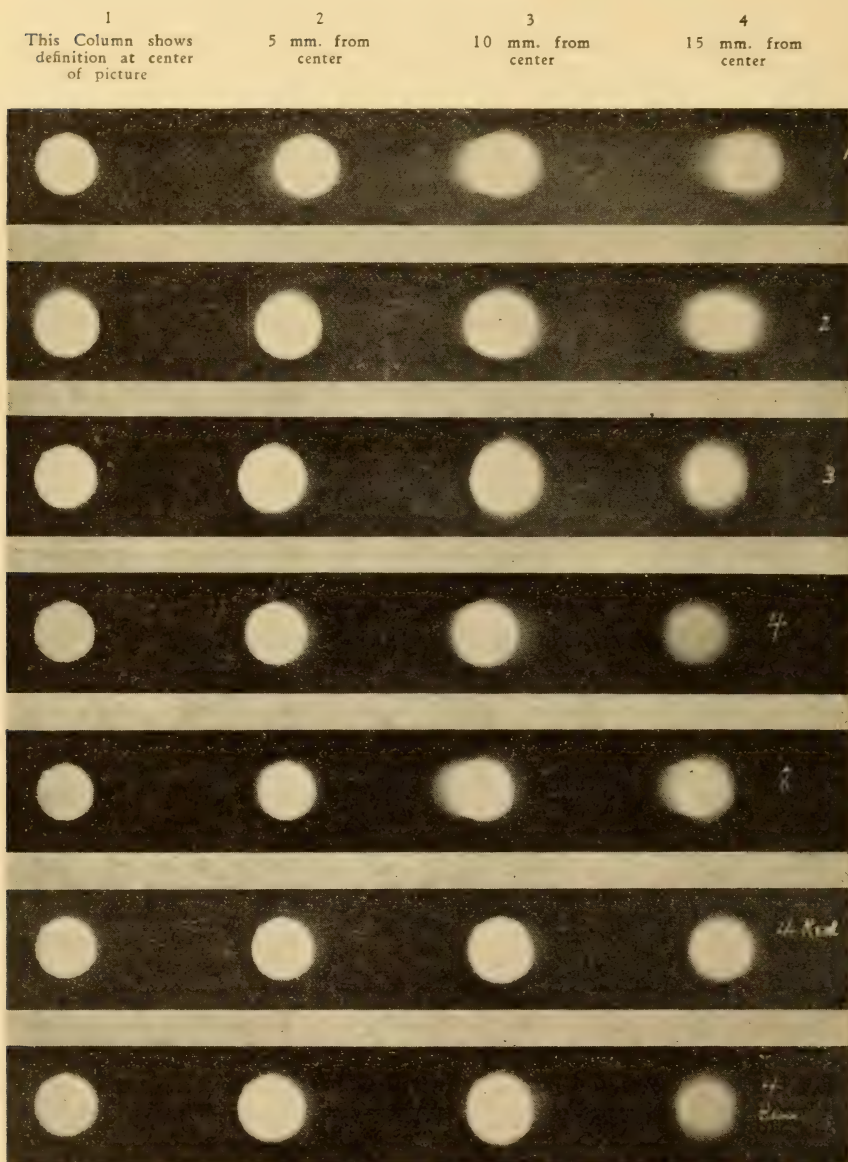


Fig. 2

method. It is a question, however, how much detail will remain in the halftone reproduction.

The test permits an interesting study of the effect of emulsion grain on the sharpness of the picture. The two circles reproduced in Fig. 3 tell the story. Of these two circles A was produced by a 50 mm. Raytar at full aperture and is in fact the center shot of lens 4 in Fig 2. Circle B was obtained in the following manner: A circular disc of white paper of the same diameter as circle A was mounted on a black background and stationed at the place where the photograph A was taken. In the place occupied by the test plate when A was taken a piece of panchromatic motion picture negative was located. The lens was stopped down until no spherical aberration could be detected and chromatic aberration was eliminated by means of a filter. Exposures were made of several different lengths and the best negative selected from the group. This was then printed on motion picture positive by contact printing. We now had a test plate that consisted of motion picture positive with a transparent spot in it whose diameter should have been exactly equal to the diameter of the hole in the test plate from which circle A was made. This positive print was substituted for the test plate, projected and photographed exactly in the same manner as before except that the lens aperture was reduced and a filter used to eliminate aberrations. The difference in sharpness of outline in the two circles is principally the result of emulsion grain.



Fig. 3

Shows defining power of lens as compared with that of film.

From this experiment the conclusion is inevitable that in the center of the picture the lack of perfect sharpness while it depends on both residual aberrations and emulsion grain, the emulsion grain effect is greater than the aberration effect in most of the lenses tested. Getting away from the center of the field the aberration effect rapidly grows larger. Here the superiority of the Raytar lens is evident.

Reference was made above to the possibility of using such a test also to investigate the performance of a lens on different kinds of photographic material and for different kinds of light. Light differs, photographically, in respect of distribution of energy with respect to wave length. This is generally but not always apparent as a difference in color. Quality differences in motion picture practice are limited to a relatively small range. Incandescent lighting is doubtless somewhat redder than the ordinary arc or daylight but it is a mistake

to think that it has no blue in it and it is equally erroneous to think that arcs emit no red and yellow light.

At any rate, the test described above permits employing color differences as radical as may be desired. Filters running from red to blue may be introduced between the light source and the test plate, where they cannot influence the performance of the lens by virtue of any optical imperfections in the filter, and tests can be made that will indicate the performance of a lens for any desired color. At the bottom of Fig. 2 are two series of shots marked 4 R and 4 Blue. These were obtained with a 50 mm. Raytar lens focused with white light and exposed with a red and a blue filter respectively without refocusing. In spite of this very radical color difference the image quality is identical and the same as for white light. For this test an incandescent lamp was used and the filters employed were Eastman's Projection Red No. 24 and a C filter for the blue.

The result of the test was not surprising. The introduction of incandescent lighting and panchromatic emulsions into motion picture practice has led to some natural but generally unnecessary concern regarding color correction of objectives. This concern would have been well founded if low aperture lenses of 16 to 36 in. focus such as are used in commercial photography had been in question. The large aperture short focus lenses employed in motion picture photography are a different matter. For the former, the residual chromatic aberration of the colors other than those two for which chromatic correction is made, the so-called secondary spectrum, is of prime importance. In high aperture short focus lenses secondary spectrum becomes secondary in another sense. It becomes of less significance than other residual aberrations in the lens and also to mechanical considerations involving camera, film focusing, etc., hence the statement at the beginning of this paragraph.

Inasmuch as this subject has gone farther than speculation and conversation and has been discussed in the pages of the *American Cinematographer* it will not be inappropriate to look into the subject a little more in detail. We have no quarrel with any type of color correction that yields good results but we believe that it is misleading to claim there is only one type which is satisfactory. In spite of the fact that achromatic telescopes have been made since 1758 lens designers are not in complete accord as to just how achromatic telescope objectives can best be corrected for color. There is no convincing evidence that within the limits of the argument one type is not as good as another. For visual instruments of all kinds each lens designer prefers or is satisfied with color corrections possibly slightly different from those preferred by other designers and yet all of them may produce equally reputable instruments.

One reason for this, of course, lies in the fact that generally only two colors can be brought to a common focus. That means that there is necessarily a multitude of other colors coming to all sorts or other foci. If we were dealing with light of only two wave lengths the problem would be relatively simple but we have to deal with light of all the colors in the visible spectrum and the choice of which

two wave lengths to bring to a common focus becomes a problem which probably does not possess an unique solution.

There is another complication, however, in the fact that if the designer brings together into a common focus two wave lengths for a given zone of the lens, say the central part of it, these two colors do not have a common focus for any other zone, say the marginal or an intermediate zone. Hence, anyone undertaking to describe the color correction of a lens, to be accurate, must state what zone he is discussing and how the color correction varies from zone to zone. He may say that he is talking about the average effect of the whole lens for a given color when he states where the focus is for that color. This, however, is possibly still more difficult to fix than it is to prove that a given color correction (which comes very close to being a meaningless expression) is the best one to adopt. The statement that if two colors are brought to a common focus for the center, let us say, of a lens the same two colors will not have a common focus for the margin, implies the existence of spherical aberration in one or both colors. You may rest assured that there is spherical aberration in both and that it is different in amount in these two colors and that furthermore spherical aberration exists for all other colors in still different amounts. An earlier article in the *American Cinematographer* reports data supporting the above statements. ⁽¹⁾

In the presence of spherical aberration it is difficult to say what the position of best focus is—it is, in fact, impossible. Visual and photographic judgment will differ and, to make matters worse, photographic judgment will differ with exposure. Then, too, diffraction adds its bit to render the position of best focus indeterminate until with everything considered it takes sublime confidence to state where either the best visual or best photographic focus lies even for monochromatic light.

In view of this uncertainty of position of best focus, a subject discussed by H. Dennis Taylor in a very interesting little book on *The Adjustment and Testing of Telescope Objectives*, it is surprising to read in a recent paper ⁽²⁾ that a certain lens of 3 in. focus should have chromatic aberration of 0.003" according to computation but that in actual practice it was found to measure less than 0.001". Now, to be certain that there is chromatic aberration greater than zero and less than 0.001" in a 3" focus lens means that the position of best focus for each of the colors in question must be determined with an error smaller than 0.0005". In view of the uncertainty of the exact position of a focal point it is a fair question whether mere reproducibility of measurement may not have been regarded as a proof of accuracy.

The explanation advanced for the discrepancy between computation and measurement amounts to saying that the picture is taken principally by means of the light which is brought to a focus at the film and that light which is not in focus has comparatively little effect. If this is true it can easily be shown to constitute another reason for the fact that it is impossible to prove that any one type of color correction is superior to all others.

This argument is not intended to lead to the conclusion that the distribution of residual color aberrations in a lens is a matter of no concern and that it can be left to chance with the certainty of acceptable performance but it is intended to show that there is no reason to believe that slight changes in the type of color correction of motion picture lenses will result in any better average performance.

The test proposed above is a laboratory test in that it eliminates practically all of the uncertainties which are able to lead so easily to false conclusions when lenses are tested in the ordinary way but at the same time it is a practical test in that it is photographic and its results are interpretable without much effort of the imagination. They are identical with an enlargement perfectly executed of a photograph taken in the ordinary way but on a practically grainless infinitely thin emulsion with almost perfect precision of focus and with a perfect camera. The tests need nothing to supplement them to disclose all the characteristics of the performance of a lens except a test for distortion. This, in fact, could be determined from a test of this sort but it would have to be carried out in a somewhat different manner.

(1) Bielicke, *American Cinematographer*, September, 1928, page 13.

(2) Dubray, *American Cinematographer*, November, 1930.

MAKING MATTE SHOTS

*Fred W. Sersen**

WRITING this article is rather an unusual way of expressing my thoughts, as I have been used to doing so by means of paint and brushes for the last twenty years, and juggling the pen is somewhat clumsy. The editor asked me to write something about "matte shots" as we call them in this studio, and I will try to describe the process of making them and how they can be used to best advantage.

Some will say "we have 'glass shots' and 'miniatures,' why use matte shots at all?" There are times when either one would do and again there are cases when some process will do better than others. I will enumerate some instances when the matte shots can be used to better advantage than anything else.

Sometimes the sets are not exactly as they should be, due to many reasons—incidents that come up daily—such as changing the script at the last minute, or the director may have some idea of his which came to him on the spur of the moment. Or the cameraman may see better composition if he shoots the set from a different angle, due to change of light or some other unforeseen reason, or to create a beautiful scene where one did not exist.

The use of a matte enables a cameraman to make the picture he visualizes. He is no longer limited by the size of the set, poor light, etc. It makes it possible for him to create and carry out the ideas he has for the enrichment of the production. I have seen cameramen by the use of ingenuity and mattes double the value of a production.

For instance: A company went to Nevada to photograph some battle scenes in a snow storm. To build the sets there would have been very costly, while without them the desired Russian atmosphere could hardly be obtained. (It happened to be a Russian picture). While they were walking around looking for the most suitable locations, they happened to run across an old concrete dam. The cameraman, being of a highly creative mind, began to visualize an old fortress connected with that wall of concrete, and before long he had a matte cut out of a piece of card-board and placed in the matte box so as to block out that piece of scenery where the fortress was supposed to be. The scene was photographed and was finished in the studio very successfully showing a fortress of great production value.

In cases of this kind it is necessary for the cameraman to be able to visualize the complete scene so as to be able to make a matte in the right place and provide enough space for the object to be painted in. He has to use good judgment as to how sharp a matte to make. If there are definite lines in the picture it is easier for an artist to match to the sharp lines and it is best for the matte to be placed about thirty inches from the camera, even further if the glass or the material to be used for the matte is easy to obtain. Again when matting to the

* Chief of Art Department, Fox Studios.



Landscape painted by artist and put in by matting out portion of first shot and then double-exposing it in



Portion of set built at studio in which the player moves and is photographed.

footage (especially when there is any wind blowing) or when dust is created by action in the scene, in a rain or snow storm, very soft blend is desirable and the matte should be placed four to six inches from the lens.

It is a difficult thing to make a good combination shot of rain, snow or dust storm with a glass or miniature, because of the distance between the real set being so much greater than that between the glass or miniature and the camera. In this case the matte shot is much the best. By double exposing or double printing the rain or whatever it may be, all over the film, makes it a perfect shot.

In combination shots where the mechanism of the miniature is too complicated, or if there are any other reasons that might delay the company while shooting, mattes are the most plausible remedy.



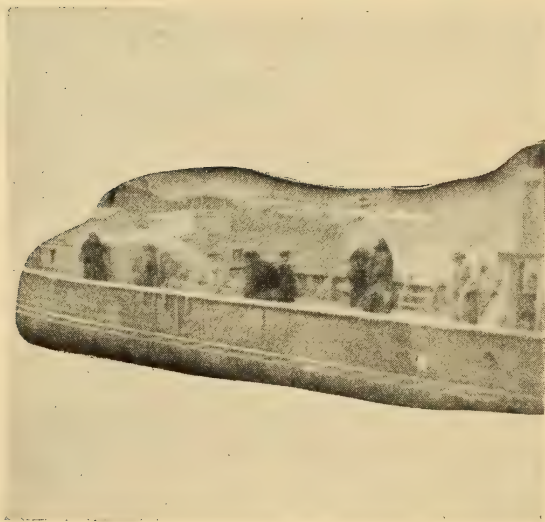
The finished product; result of the efforts of the artist and the cameraman.

The process is very practical—when putting two or three exposures together, by matting out the undesirable portion of the picture one can double expose or double print anything right on the original negative, which eliminates the process of duping which means much to the quality of the film.

In practice the cameraman conceives the effects or settings he desires and directs his camera as if the scene existed. By using opaque paint or glass or snipping out a piece of black cardboard and placing it in a rigid position between the subject and the lens those portions of the scene are blocked out so that the film is unexposed in those parts to permit the subsequent exposure of the painting. The camera is "planted" to prevent further movement, and a test scene is made as nearly under the same lighting conditions as is possible. Then the actual scenes are made, a record being kept of the footage, fade-outs, etc.



Portion of ship in miniature, cutting through ice, with action section matted out.



*Section of ship built on stage and matted out by cameraman.
Here action takes place.*

The test film, of which we usually have about one hundred feet, and the scene itself is turned over to the artist undeveloped. We take a few feet of the test and develop it, and this is used for lining up. There are several methods that can be used for lining up a "matte shot."

One can project the film through a camera on to a highly colored surface on which the artist is going to paint, and draw the outlines of the objects of the first exposure, which gave the base to draw to. After the drawing is completed, it is laid in with oil paint in black and white, and on the artist's ability and experiences depends the matching of the tones of the first exposure, which is ascertained by making the hand test and comparing the tones. He does this re-



Finished product after triple exposure and matting

peatedly by correcting the painting until the match is perfect. Another system is to line up the shot by using auxiliary aperture and looking through it to guide the drawing of the picture.

The third method is to double expose over the original exposure a black screen divided by white lines into one inch squares which are duplicated on the surface of the would-be painting, and the image of the original exposure is transferred by aid of these squares. It is the same system that is used by artists in enlarging a drawing. In all cases enlargements of 9x12 inches should be made in order to better see the details of the picture.

The system we are using in this studio and which is most practical in about seventy-five per cent of "Matte Shots" is to make an enlargement of the picture on the paper which is mounted on a specially prepared board. This gives the artist a perfect picture of the scene and he can work out his drawing, tones and composition and see the picture as a whole before he paints his reverse matte on. It eliminates a long and tedious job of lining up, which is connected with the methods previously mentioned. One can appreciate the advantages

of this system better when there are numerous objects to match to a very accurate printing. To demonstrate this, I would describe a shot I made of changing Michigan Avenue in Chicago from a day to a night shot.

We took a day shot of Michigan Avenue with automobiles and pedestrians in busy commotion as only American thoroughfares can be, and had an enlargement made of it. I painted the enlargement of the day shot into a night effect and the match was so perfect that in a four-foot lap dissolve one could not detect any variation in form whatever. It was a rather complicated shot and here is the process we used. Day shot was duped with four-foot laid out. Into that we lap the painting of the city at night, and the automobile traffic was double printed in by using positive of a film we photographed on the local street which was exactly the same width and same elevation as in the day shot. The shot had to be photographed at dusk when the head-lights of the automobiles were on. The pedestrians on the side walk were printed in from the day shot as well as the lower part of the first stories of the buildings, with automobiles parked against the curb. Only those acquainted with this type of work can fully understand what it takes to balance the lighting and painting of these separate parts of a picture and what perfect mattes had to be used in printing hard edges of the automobile contours.

The enlargement comes handy when we have three or more exposures to be put into one picture. By making separate enlargements on the same piece of enlarging paper will give us perfect outlines to the mattes which are used for double printing as well as the connecting painting which is double exposed in. For instance, we had part of a boat built for the action of people moving about on deck which was backed up by painted backing. This was to be made into a picture of the boat cutting through ice in the Arctic sea, with the clouds passing by. We built the hull of the boat in miniature which matched the set boat built for the scene, and photographed it with speed camera, the miniature ice floating by. This was double printed into the original take, and painted to connect the two, and the rigging was doubly exposed afterwards. The real clouds were photographed moving in the proper direction, aided by panning the camera, and then double printed in, which required some fine matting.

Too much attention cannot be paid to the steadiness of the exposure, as the least movement in the film will cause a distinct movement between two exposures. The films should be measured so the perforations would be perfectly cut into the film when intended for matte shots, and the camera buckled down securely.

All the work should be done through a camera fastened to a title block fastened to a concrete pedestal.

IMPROVEMENTS IN MOTION PICTURE FILM

*Hal Hall**

THE past year has been one of continued progress in the technical department of the motion picture industry. But, perhaps, the greatest progress has been made by the manufacturers of motion picture film. The scientists of the research departments of the film manufacturing companies are to be congratulated, for they have produced results that have lightened the burden of the cinematographer and photographer and have made possible photographic achievements which even a year ago would have been considered impossible.

When panchromatic film was introduced it appeared as though the ultimate had been reached in motion picture negative. After the old orthochromatic negative, the panchromatic seemed lightning-fast, and the quality of motion picture photography improved tremendously. But, excellent as was the film, the scientists in the laboratories of the film companies were not content. They felt that something better could be produced. They worked ceaselessly.

The result was the announcement last February, first by the Eastman Kodak Company, followed immediately by the Dupont Film Company, of a new motion picture negative with speed such as had only been dreamed of before. Eastman called its film "Super-Sensitive Panchromatic Type Two". Dupont called its new film "Special Panchromatic". Among the craft in Hollywood they are both referred to as "fast film", which expression the writer will use throughout this article.

Among the outstanding claims on the part of one of the film makers when they announced the film were the following: 1—the fast film is twice as fast to daylight and three times as fast to tungsten light as the panchromatic in use up to the time of the introduction of the new film. 2—the fast film shows 75 per cent more speed to blue light, 200 per cent more to green light and from 400 to 500 per cent more to red light. 3—the fast film exhibits an appreciably softer characteristic than the regular panchromatic film. For the same development the new fast film gives lower gammas, making it advisable to develop the fast film longer if the same degree of contrast as in the past was desired. 4—fast film must be handled at a much reduced light intensity in the dark rooms.

Unlike so many manufacturing organizations, the film manufacturers do not make claims for their product that they cannot substantiate. Their claims for the new film were adequately fulfilled. The new film was all they claimed, and cinematographers began shooting pictures with so little light that a casual visitor to a studio might think the cameramen were merely lining up or making unusual tests.

* Editor, *American Cinematographer*; Editor, *Cinematographic Annual*.

Cinematographers universally rejoiced and photographic results were universally better.

Much of a theoretical nature has been written by the experts of the film companies. Several of these special articles will be found appended to this article. However, the writer here will attempt only to bring out the more practical aspects of the new film and its use, and will leave the curves and more technical details to the men who are far more able to discuss them.

While much stress was laid at first upon the speed of the new film and the fact that it was approximately fifty per cent more sensitive to daylight than the old film, this speed, to the cinematographer, is not as important as the fact that this new film makes possible a tremendous improvement in photographic quality, due to its immeasurably superior rendition of color.

Oliver Marsh, A.S.C., one of Hollywood's well known cameramen, in writing about this new fast film for the *American Cinematographer* magazine¹ gives some practical views that should be of value to the readers of this article. He speaks after photographing two productions and after making extensive tests.

"After all", says Mr. Marsh, "it is of relatively little importance to the studio cinematographer that the film is some forty per cent more sensitive to light. Such monetary saving in electric current as is possible would be valueless if the quality of the picture is harmed. Therefore, this new fast film is of merely minor importance if it brings only increased speed without improvement in photographic quality. But if it brings not only a considerable increase in speed, but also a proportional increase in photographic quality, then, truly, it is a great advancement in cinematographic technique. And this new film is exactly that.

"It gives an increase in speed of some forty per cent and it gives an even greater improvement in photographic quality—which represents its real claim to importance for studio work. Speed alone is sometimes an advantage in studio production, but improved photographic quality is invariably of vital importance. And, since the new fast film embodies both these qualities to a high degree, it is of actual, practical value in our exacting work".

There is the practical man's viewpoint, and when a man of the ability of Mr. Marsh speaks as he does it means that real achievement has been attained in the new film.

The matter of color rendition with the new film is an important one. And it is in color rendition that the new film excels. It is generally conceded that the best color rendition is that which most closely approaches the natural visual brilliancy. The old Orthochromatic film distorted these relative values very badly, despite anything that the cinematographer could do with filters and careful arrangement of lights. The cinematographer had to be satisfied with that film until Panchromatic appeared. That was a memorable advancement. But then came Mazda lighting and an improved panchromatic emulsion. By that time the cinematographers had learned to use the new tool quite effectively, and good color and tonal rendition

resulted. Now, with the new film, while absolute perfection has not been reached, perhaps never will be, the improvement in color and tonal rendition is improved to a marked degree and cinematography has benefited thereby.

Blues no longer reach the screen as muddy whites; nor do reds and greens photograph between a dark gray and a black. Intermediate colors reproduce in a respectable range of half-tones. With the new fast film the camera can now see objects as do the cameramen's eyes. When the Art department hands the cameraman a set to photograph the cameraman knows that he can place that set on the screen with its tonal qualities practically intact, though in monochrome. The time and ingenuity of the cinematographer is no longer spent in effort to prevent the distortion of the tonal contrasts achieved by the art directors and costumers. The new film takes care of that.

However, to secure these advantages of tonal quality and color separation the cinematographer must make sure that they are first in the set and that the sets are then lighted in a manner that will enhance these tonal contrasts. Some cinematographers when first trying out the new film overlooked the importance of these details and were naturally disappointed with their results. Too many cinematographers confuse the improved speed with exaggerated contrast—a serious mistake. The aim of the cinematographer should be for natural tonal contrast with an artistic softness—and this softness cannot be attained with flat lighting. Soft lighting should be used—but it should be normally balanced, sacrificing none of the tonal and physical contrasts which the cameraman wishes to preserve. As a rule the cameraman should take pains to enhance the contrasts he wishes to preserve, trusting to the new film not only for better color separation but for desired softness as well.

As no two cinematographers work in exactly the same manner, the less said about lighting the better. However, one bit of excellent advice is to always remember that just because the new film is forty or fifty per cent faster than the old is no reason the cameraman should be deluded into altering the balance of his light.

Mr. Marsh adds some excellent advice in that line when he says: "If you can make a forty per cent decrease in the total amount of current consumed on your set, well and good; you can save a lot of money that way. But if you try to make this reduction in light at the expense of your natural balance, it will seriously affect the quality of the picture. Don't be deluded into trying to make this reduction in the number of units you use, for you must have a certain number of light sources to preserve the balance of your lighting. Use smaller globes in your present equipment and arrange things as you always have. In that way you will be able to secure all the advantages of the new film without running the risk of the inevitable disappointments which attend its unintelligent use. You will find that the tonal quality, color separation and general gradation of your picture will

be vastly improved, and with this improvement will come a surprising improvement in perspective."

This writer has seen comparative tests of the new fast film and the old in which the difference in perspective was so marked that cameramen have doubted that the same lens was used.

Mr. Clyde DeVinna, A. S. C., another master of the art of cinematography, also has some very timely remarks² on the subject which may be of assistance to the cameraman who has not yet tried the new fast film.

"In addition to working faster and with more comfort, and therefore greater efficiency for all concerned," says Mr. DeVinna, "this new film makes possible a tremendous increase in photographic quality"—almost the same words as those of Mr. Marsh. "Unusual overall sensitivity is of little real importance in studio use, except as it enables a reduction in the amount of lighting equipment used, and thus improves the working conditions on the set. But there can be no substitute for color sensitivity. The color sensitivity of the new emulsion is truly a remarkable improvement over the old. It is much more uniform, and closer to the sensitivity of the human eye. In other words, colors now photograph more nearly as we see them. Furthermore, this new fast film has inherently a color correction which approximates somewhat the correction obtained on the old type of film with a K-3 filter. This, however, is a haphazard way of putting it; but it gives us an approximate index as to what we can expect. From it we can at least get an idea of where we start; that is, with a film which has the same general chromatic advantages as the older film with the filter stated, but without the overcorrection frequently noticeable.

"To my mind, the greatest advantages of the new film come in exterior work. In the long series of tests which I have made on exteriors with it I have not yet found any way to make this film give an unpleasantly harsh, contrasty picture. You can over-correct upon it, but you cannot make it go contrasty. Even under the most absurdly impossible filter and exposure combinations, and for all night effects, it will still give a naturally soft picture, with surprisingly luminous shadows, and soft high lights.

"Even without filters, it is surprising what the new film will do in the way of cutting through the haze of distant landscapes. It will pierce haze that the eye will not, yet at the same time keep a nice atmospheric balance. With filters it is sometimes embarrassing, for with these aids it will ruthlessly rip its way into the distance and reveal more than you have bargained for. The new film is a great aid to the user of the long focus lenses. Such lenses have a disconcerting habit of giving a flat picture at times, unless the exposure and lighting are very accurately managed. The new film goes a long way to remedy this trouble. I have made tests with extreme telephoto lenses and this film, panning my camera so that the light through the shot changed from a straight cross light to a perfect back light. At all times the shot stood out as crisply and nicely as though it had been done with a normal lens."

So much from the practical experience of the cameramen. It may be of help to the new users of this new film to mention the subject of filter factors. D. R. White of the DuPont Film Company's research laboratories, explains³ that the filter factors for the DuPont fast film and the DuPont regular panchromatic are the same within very close limits. He points out that the lens stop or lighting used with the fast film should be reduced to take account of the increased speed, but, points out that the filter factors themselves are essentially unchanged.

"As all successful filter users know," says Mr. White, "the correct filter factor for a given set of conditions depends upon three things: the filter, the lighting and the sensitivity of the film. It is, of course, usual to specify a certain type or source of light and prepare a table showing the factor by which the stop should be increased to make up for the light absorbed by each of a series of filters. This is thoroughly satisfactory only when the light source is constant in quality from time to time and place to place. Daylight is not constant in either way, but must be used for so much of the work where a filter is needed that filter factors for it are of great interest."

Mr. White then gives the following table of filter factors for the Wratten filters for sunlit scenes for both the regular DuPont panchromatic and the new fast DuPont negative:

Filter	Filter factor
K 1	2.2
K 2	3.1
K 3	4
G	5
F	10
A	7
B	16
C	12

These factors were obtained in sunlight and show the factor by which aperture or time should be increased to compensate for filter absorption, explains Mr. White. And he goes on to say that where the light quality is not of sunlight these factors cannot be expected to hold accurately, and a test shot should, of course, be made if the work is quite critical. Experience, he points out, has shown that for shadow shots, when there is an absence of sunlight but a predominance of light from the blue sky, the factors for blue absorbing filters should be increased somewhat over the values given; and for the blue transmitting filters, if used, somewhat decreased.

Dr. L. M. Dieterich, A. S. C., has worked out a rather comprehensive table⁴ governing the use of standard filters with the Eastman panchromatic Type 2 negative and the new Eastman supersensitive, or fast, film. This table which is shown on page 98 can be taken as approximately correct, and should be of considerable value to the cameraman. However, it must always be remembered that the multiplication factors for various filters are only an approximate guide and subject to sometimes radical changes when either stop values or shutter openings are selected. The color values of the object, the character of the illumination or light source, the actinic spectrum reaction of the emulsion, the desired emphasis of certain colors, special effects

**F TABLE FOR STANDARD FILTERS AS USED WITH
EASTMAN PANCHROMATIC No. 2 AND EASTMAN SUPERSENSITIVE PANCHROMATIC**
(Approximately correct)

Without Filter										f values with Filter (daylight filter factors and 170° Shutter opening)																	
No. 2			S		Aero No. 1		K 1		K 2		K 3		G		A		B		C		F						
f	%	f	%	No. 2	S	No. 2	S	No. 2	S	No. 2	S	No. 2	S	No. 2	S	No. 2	S	No. 2	S	No. 2	S	No. 2	S				
1	100.00	1.7	33.33		2.46								1.44														
1.5	44.44	2.6	14.81	1.24	2.94								2.12														
1.8	30.86	2.9	10.28	1.46	4.4								2.51			1.3					1.44						
2.3	18.89	4.0	6.29	1.88	5.8								3.14			2.1					1.72		1.08				
2.7	13.71	4.8	4.57	2.22	6.2								4.2			2.32					2.24		1.34				
3.0	11.11	5.2	3.70	2.48	7.2								4.4			2.62					2.58		1.64				
3.5	8.16	5.9	2.72	2.75	9.4								5.0			3.00					2.84		1.8				
4.0	6.25	6.8	2.08	3.22	9.8								5.6			1.02					3.10		2.1				
4.5	4.93	7.8	1.64	4.00	11.0								6.3			1.14					4.0		2.5				
5.6	3.18	9.6	1.06	4.30	14.0								7.8			1.32					4.4		2.75				
6.3	2.51	11.0	0.83	5.40	16.0								8.8			1.62					5.4		3.34				
8.0	1.56	14.0	0.52	6.4	20.0								11.4			1.82					5.9		4.0				
9.0	1.23	16.0	0.41	7.4	22.0								13.0			2.34					7.8		4.9				
11.0	0.82	18.0	0.27	9.00	28.0								16.0			2.64					8.6		5.6				
16.0	0.39	28.0	0.13	13.00	32.0								22.0			3.16					10.6		6.8				
22.0	0.20	32.0	0.06	18.40	Sh								32.0			4.8					15.5		9.6				
32.0	0.08	Sh	0.03	25.00	Sh								32.0			6.9					22.0		14.0				
				25.00	Sh								14.2			9.0					32.0		20.0				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
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				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				25.00	Sh								15.0			9.0					10.0		6.3				
				2																							

radically different from correct reproduction of inherent object characteristics—all these various conditions influence the selection and proper use of filters and the determination of correct exposure by stops and shutter opening control.

Special care must be taken in the dark room handling for camera loading and processing of the fast negative. It is best to do it in total darkness. If extreme caution is taken a dim green safelight may be used which will permit some vision and still not fog the film in exposures of a few minutes duration. As the use of any light in the dark room may lead to disaster, it is suggested that you make tests with your green safelight before taking chances on ruining a quantity of film. This is easily done by simply exposing a small strip of negative to the dark room conditions when the green safelight is on. Then develop it and you will soon know whether or not the light is too strong. It is an excellent idea to take a piece of black paper and wrap it around part of the strip of film. Then expose a portion to the green light for a certain length of time. Then slide the paper along and expose another strip for a different length of time. In this way you can tell quite satisfactorily the duration of time you will have for handling in loading or processing. And it must always be remembered that you should figure on a factor of safety to allow for a possible variation in handling time. All in all, it is best to handle the film in absolute darkness unless the value of the presence of light is great enough to warrant the planning, testing and continued watchfulness required for safety.

Hardly had the industry stopped gasping over the new fast film when another improvement was announced by both the Eastman and the DuPont film companies. This was an improvement of almost as great importance as the fast negative. It was a new anti-halation base on the new high speed negative—an improvement which removes one of the bug-bears of the cameraman, namely halation.

Halation is defined as a halo of light sometimes seen around the image of a bright object in a photographic print. In a negative it appears as a flare of silver along the edges of the bright object. It is most likely to occur in photographs of bright incandescent lamps, of strongly back-lighted objects, of interior scenes, including sunlit windows, or of the outline of a building against a blue sky. As has been said by Dr. V. B. Sease, A. S. C.,⁵ it is clearly a phenomenon of scattered light. Photographers have always been troubled with this halation in their pictures. The halation is due, says Emery Huse, A. S. C.,⁶ to light which has penetrated the emulsion and which is reflected back into the emulsion again by the back of the support.

This halation is a very serious matter on glass plates, but in ordinary photography in which film with a thin base is used it becomes quite negligible. However, halation is a relative matter and the spreading of light on an eight by ten might be utterly negligible, but very serious in the small sized motion picture frame. Negative film, therefore, for years has been made with a double coating of emulsion so that in addition to the other benefits conferred by this procedure, halation was reduced to a minimum.

As early as 1867 an American inventor secured a patent on a black backing for collodion plates. This was as a remedy for halation which then was causing the photographer much trouble. Those early workers were seeking a way out of the halation difficulties and sought to remedy the situation by various ways. They recognized the fact that the rear surface of the glass or celluloid support was a reflector of light since the index of refraction of these materials is different from that of air. So they coated the back of plates with caramel or other substances whose index of refraction is similar to that of glass, in order to try and eliminate the rear reflective surface. Such procedure accomplished the desired result and could be washed off easily. A number of substances were tried out throughout the years, such as asphaltum in benzene, or dyes in collodion, gelatine and the like.

Some attempts were also made to put a substratum coating under the emulsion which would be capable of absorbing the light to which the emulsion is sensitive. One inventor put a dyed gelatine coat between the emulsion and the plate. Another recommended a coating of transparent red, orange or green dye between the emulsion and the plate. And so it went through the years, a constant struggle to wipe out the bugbear called halation.

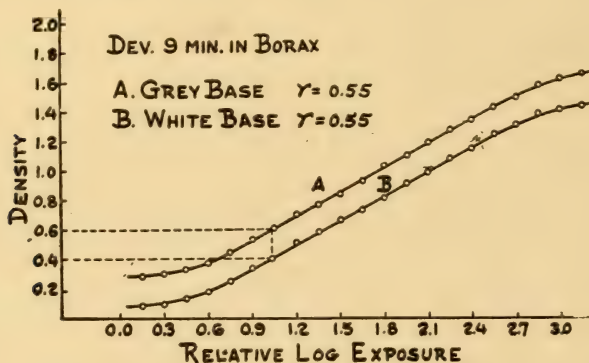


Fig. 1

In the motion picture industry it did not seem desirable to place a soluble background upon the negative motion picture film, but another method was found to overcome the halation difficulty. It consists of the putting of a light gray backing or base on the film. This completely obviates halation. And as stated by Huse⁷ this gray base does not change during processing, so involves no danger of chemical trouble. Quoting Huse we are told that "anti-halation backings have no direct chemical effect upon the emulsion characteristics. However, there is a decided enhancement of photographic quality effected by the avoidance of scattered light from the base side of the film. The removal of the scattered light, then, gives the effect of different emulsion characteristics, although this effect is arrived at indirectly and not as an alteration of the emulsion."



*Fig. 2
Photographed
on regular
film.*



*Fig. 3
Photographed
on film
with gray
base.*

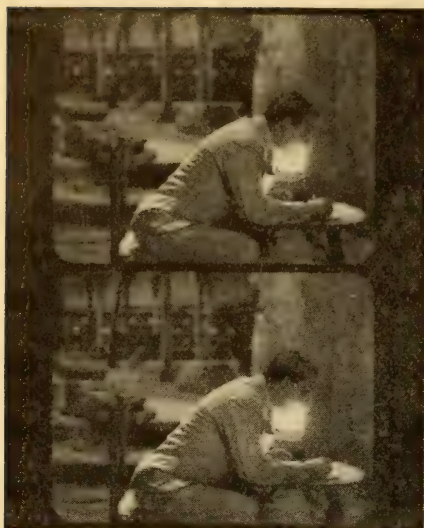


Fig. 4
Photographed on regular film.

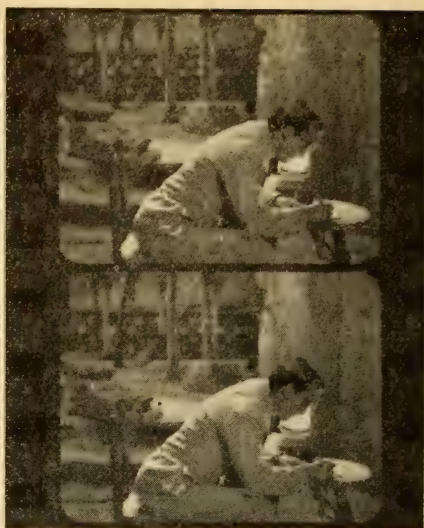


Fig. 5
Photographed on grey base film.

Huse further points out that "from a technical standpoint the only difference in handling procedure demanded by gray back film is a consideration of the gray base density, which amounts to approximately .20 (63 % T) in measured density after developing, fixing, washing, etc. The sensitometric difference is very slight, amounting only to a displacement to the left of the H and D curve, as compared with a similar test on white base."

Figure 1 illustrates this point, showing for the same emulsion coated on gray base and white base the actual sensitometric difference. Huse explains that as a result of this base density an increase of approximately $1\frac{1}{2}$ to 2 printer points is necessary. Figures 4 and 5 give an excellent example of what the new anti-halation film achieves. Both were photographed under the same conditions—one on white base, the other on gray base. The illustrations speak for themselves.

The writer has tried in his feeble way to bring out some of the practical points regarding the advancements made by the film makers. The following two articles by Emery Huse and Gordon Chambers of the Eastman Kodak Company and by D. R. White of the DuPont Film Manufacturing Corporation, will deal with the theoretical aspects of the new films.

References:

1. American Cinematographer, May, 1931, page 11.
2. American Cinematographer, June, 1931, page 13.
3. American Cinematographer, April, 1931, page 17.
4. American Cinematographer, March, 1931, page 14.
5. American Cinematographer, July, 1931, page 14.
6. American Cinematographer, July, 1931, page 15.
7. American Cinematographer, July, 1931, page 39.

EASTMAN SUPERSENSITIVE PANCHROMATIC TYPE TWO MOTION PICTURE FILM

*Emery Huse and Gordon A. Chambers**

ON FEBRUARY 5, 1931, the Eastman Kodak Company announced to the motion picture trade in Hollywood, California, their new Super Sensitive Panchromatic Type Two Motion Picture Negative film. Inasmuch as this film exhibits characteristics not hitherto shown in motion picture negative emulsions, it was considered advisable to present some data pertaining to those characteristics. This article is not presented as a complete technical treatise of the characteristics of the Super Sensitive film, its aim being to call attention briefly and simply to the differences this Super Sensitive film exhibits over the present type of panchromatic films.

As the name, Super Sensitive, implies, this emulsion is extremely fast but because of its name this new film must in no way be confused with a hypersensitized film. In the past when an emulsion of extreme speed was desired, either for color photography, filter shots, or trick work, it was customary to especially treat the film with some type of sensitizing bath. This bath caused a general increase in the emulsion speed and particularly increased the red light speed. However, the hypersensitized film had certain disadvantages such as its cost, its lack of keeping qualities, and its propensity to produce fog. With the Super Sensitive Type Two these disadvantages are entirely overcome. The increased speed of the Super Sensitive film has been accomplished during the course of the emulsion manufacture. It is sufficient to say, therefore, that the Super Sensitive film is not a hypersensitized film. Furthermore, the Super Sensitive film exhibits the same keeping qualities and shows identical physical characteristics as those shown by the present panchromatic films.

A complete study of any type of film emulsion is best accomplished by making both sensitometric and practical camera tests. This article will not deal in any detail with camera tests but will consider in some detail the sensitometric characteristics of the Super Sensitive emulsion as compared with the present type of panchromatic film. The point of major importance in the consideration of the Super Sensitive film pertains to its greatly increased speed. The data obtained sensitometrically can be and have been checked by camera exposures.

Sensitometry involves a study of known values of exposure as related to the amount of silver (density) which these exposures produce upon the film after development. The standard sensitometric curve is therefore one in which is shown the relationship between exposure (expressed logarithmically) and the densities produced. It is from curves of this type that the sensitometric characteristics of the films under investigation have been studied.

*West Coast Division, Motion Picture Film Department, Eastman Kodak Company.

Another important consideration in studying the need of the Super Sensitive film necessitates a study of the quality of the light sources to which this film is exposed. For that purpose sensitometric tests have been made to daylight and to tungsten. Inasmuch as the mode of testing an emulsion to any light source is practically identical we shall for the sake of brevity and clarity consider only the curves obtained by exposure to tungsten.

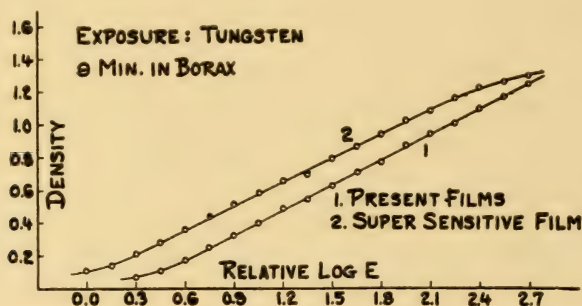


Fig. 1

Figure 1 shows the sensitivity curve of the present and Super Sensitive type of film for tungsten exposures developed for a fixed time, nine minutes in a standard borax developer. It will be observed that the Super Sensitive curve lies above the curve for the present type of film and the separation of these curves gives an indication of the speed difference existing between the two films. In making a numerical estimate of the speed we do not consider the actual density values produced for a given exposure. The customary method is to deduce speed from the exposure value obtained at the point where the straight line portions of these sensitivity curves, extended, intersect the exposure axis. Speed, is actually defined by the following formula:

$$\frac{1}{i} \times C = \text{Speed,}$$

where i , the inertia, is the exposure value of the intersection point and C is an arbitrarily chosen constant. For the curves shown in Figure I we find that the speed of the Super Sensitive film, as represented by curve No. 2, is three times that for the present type films. Identical tests made to day-light show that the Super Sensitive film is twice the speed of the present type. With reference to Figure 1 attention should be called to the marked difference in the low exposure region, that is in the toe of the H and D curve. In this region the Super Sensitive film definitely differentiates between exposures of very low intensities. Particular reference is made to the exposure region to the left of the relative log exposure value of 0.3.

The cause for the difference in relative speeds between the two types of films to tungsten and to daylight, or to any other source, is entirely dependent upon the color distribution of light from the

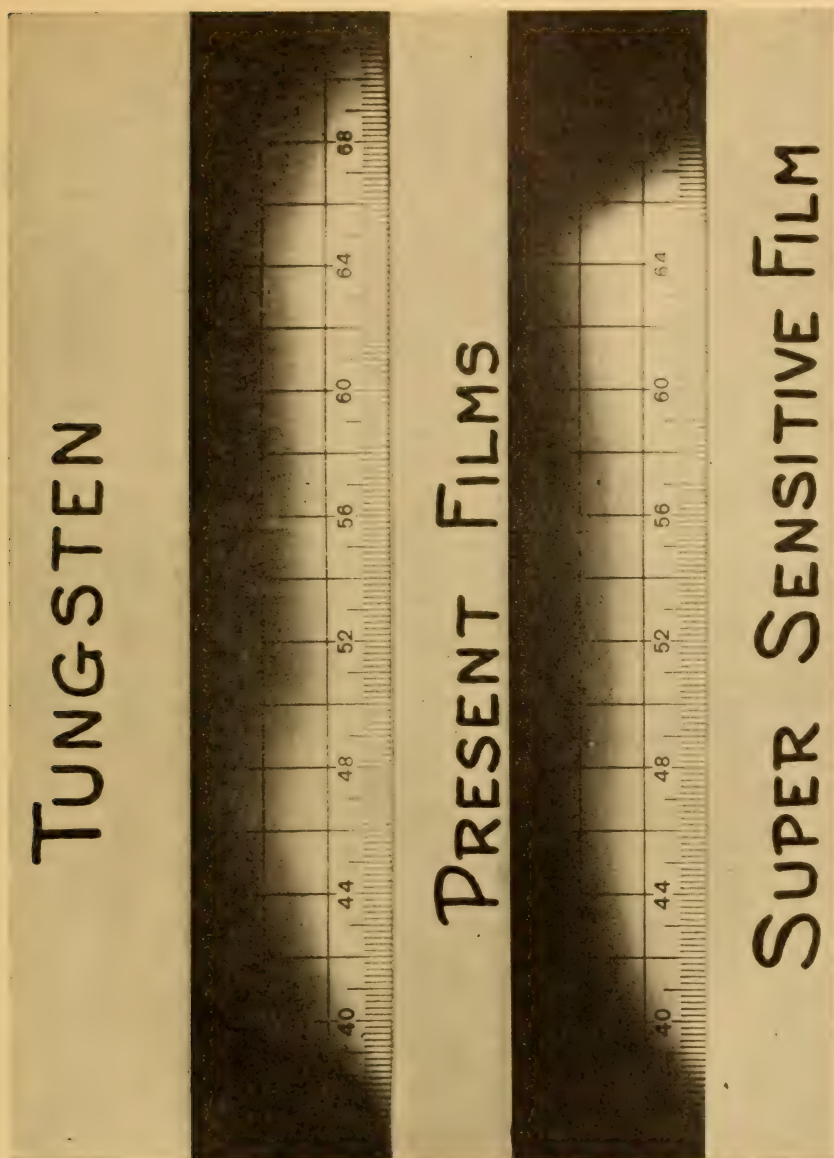


Fig. 2

source and its effect upon the color sensitivity of the emulsion. It is generally known that tungsten, for example, contains a greater proportion of red light than does daylight, and the difference in speed of the two films indicates that the Super Sensitive film must possess greater sensitivity to red light than the present type of film. It is mainly for this reason that the tungsten speed of the Super Sensitive when compared to the present type of film is greater than for a similar comparison to daylight.

The difference in color sensitivity of the two types of films is shown in Figure 2. This figure shows prints of spectograms of the two types of film when exposed to tungsten. Speed comparisons should not be drawn from these prints as the prints are so made to show the regions of the spectrum to which each emulsion is sensitive. The figures given represent wave lengths and beginning at 40 in the blue violet region we have increasing wave lengths through the blue violet, blue, green, yellow, and orange as far as the deep red given at a wave length of 68 microns. The Super Sensitive film shows an increased concentration of sensitivity in the region around 64 microns. The Super Sensitive film confines its sensitivity to the definitely visible portion of the red end of the spectrum, while the present type of films shows an extension into the deep red and encroaches upon the near infra-red region. This concentration of visible red sensitivity gives a marked advantage to the Super Sensitive as it is the extension of red sensitivity into the region of longer wave lengths which is a contributory factor in the production of chalky highlights under tungsten illumination. This is eliminated to a marked degree with the Super Sensitive film.

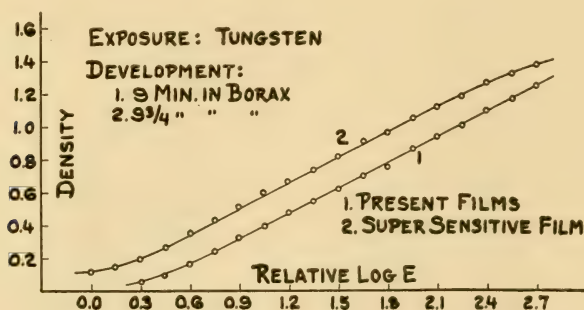


Fig. 3

A complete study of an emulsion's sensitivity to color necessitates actual speed measurements to the three major portions of the visible spectrum, namely to blue, to green, and to red light. For the purpose of obtaining such information actual speed tests, similar to those shown in Figure 1 and later verified by practical exposure, were made to daylight through the No. 49 (blue), 58 (green), and 25 (red) filters. Speed values determined from such tests show that the Super Sensitive film has 75 % greater speed to the blue, 200 % greater for

the green, and from 400 to 500 % greater for the red exposures. Such sensitivity naturally lends to a better and more intelligent use of filters, either for straight photography or for trick work.

Another important consideration in the comparison of present and Super Sensitive film pertains to contrast and the rendering of shadow detail and softer highlights. Figure 3 shows for tungsten exposures the difference in time of development between the two types of film to produce equal degrees of contrast (gamma). These curves are of equal gamma and the data contained shows that it was necessary to develop the Super Sensitive film three quarters of a minute longer to produce this effect. Furthermore, greater density is picked up in the low exposure region. This is mostly accounted for by the increased speed of the Super Sensitive emulsion, but it is this ability to pick up and differentiate between these low intensities which gives the high order of shadow detail rendering which is shown by this Super Sensitive emulsion. On the other hand, in the region of high exposure it will be observed that the Super Sensitive film shows a tendency to break into a shoulder, while the present film continues as a straight line. This is at least true for the series of exposures shown in the figure. This break into a shoulder lends to softer highlight rendering and still permits of very definitely separating highlight intensities and thus produce details in this region.

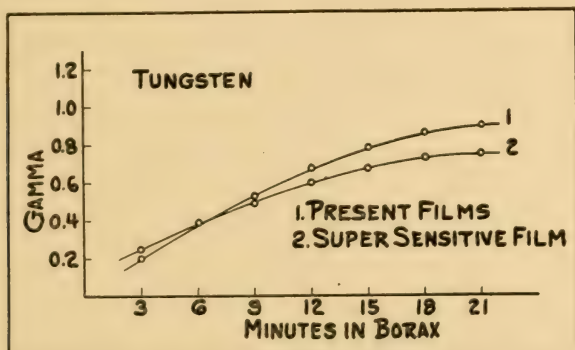


Fig. 4

Figure 4 shows in much more detail the relationship existing between contrast (gamma) and time of development. These curves, made from exposures to tungsten, represent what are commonly referred to as time-gamma curves and they show the rate at which gamma builds up with increasing time of development. The rate of increase of contrast with increased development time is appreciably less for the Super Sensitive film, as will be shown by a study of the curves in Figure 4. This means that in the handling of the film during development there is relatively little chance of either under or over developing. Errors of the order of 25 % in development time will have a much less marked effect on the Super Sensitive film. In other words the Super Sensitive film gives to the laboratory man that one

thing which is so important to him and which is colloquially referred to as "development latitude."

There is just one caution which should be mentioned at this time. Due to the increased sensitivity of this emulsion, the handling of this film cannot be successfully accomplished unless the illumination from the present safelights is reduced appreciably. The ideal condition under which to handle this film would be total darkness and no doubt this condition will prevail inasmuch as many camera loading rooms and laboratories which process negative on machines now operate in almost, if not total, darkness. It is felt, therefore, that this will not work any great hardship on the laboratory. However, this word of caution is considered necessary because of the greater increased speed both to white and to colored light of the Super Sensitive emulsion.

It is felt that a summary of the outstanding features of the Super Sensitive film will bear repeating.

1—Super Sensitive film is twice as fast to daylight and three times as fast to tungsten light as the present type panchromatic films.

2—Super Sensitive film shows 75 % more speed to blue light, 200 % more to green light, and from 400 to 500 % more to red light.

3—Super Sensitive film exhibits an appreciably softer characteristic than present films. For the same time of development the Super Sensitive film gives lower gammas. This makes it advisable to develop the Super Sensitive film longer if the same degree of contrast as now accepted is still desired.

4—Super Sensitive film must be handled at a much reduced light intensity in the dark rooms.

CHARACTERISTICS OF DU PONT PANCHROMATIC NEGATIVE FILM*

D. R. White**

THE general sensitometric characteristics of Du Pont regular and special panchromatic negative emulsions are shown in Fig. 1 and Fig. 2. Fig. 1 is a family of curves representing the rate of development of the special negative and Fig. 2 is a similar group of curves for the regular negative. For all of these curves, and in fact for all sensitometric data presented in this paper, the light source was an incandescent lamp operated at a color temperature of 2475°K. so arranged as to give an illumination of five meter-candles on the film as exposed in the sensitometer when no filter was interposed between the light and the film. The exposures were non-intermittent and were increased by factor two steps in time from one exposed area to

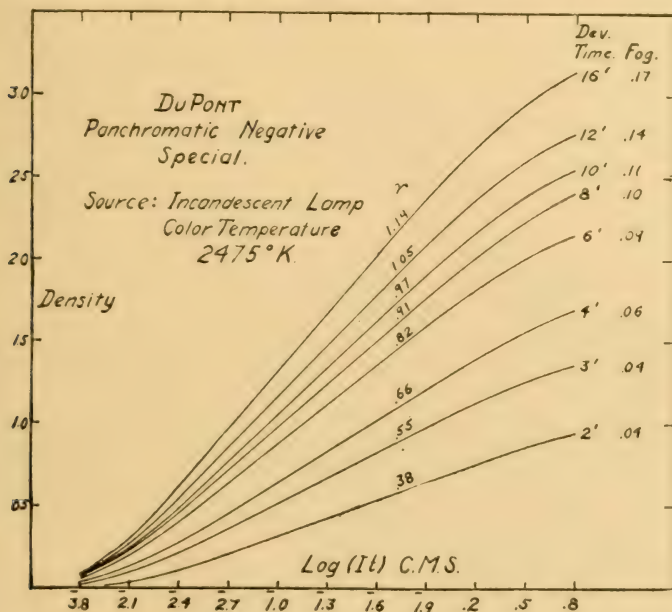


Fig. 1. Rate of development curves for Du Pont special panchromatic negative.

the next. The sensitometer was of the sector wheel type having no unusual design features, and was driven at constant speed by a synchronous motor. With the particular wheel speed used, the longest exposure was 1.25 second and the shortest was 0.00122 second. The greatest and the least exposures, expressed as the product of time and intensity, were, therefore, 6.25 and 0.0061 candle-meter-second.

* Presented at the Spring, 1931, Meeting of the S.M.P.E. at Hollywood, Calif. Published in the S.M.P.E. Journal.

** Du Pont-Pathe Film Mfg. Co., Parlin, N. J.

These values are shown on the curves by their logarithms which are, closely, 0.8 and 3.8, respectively.

The development was carried out in a borax metol formula.¹ The developer was highly agitated during the development, a procedure which tends toward reproducibility of results but which also tends toward higher gammas at the shorter times of development than

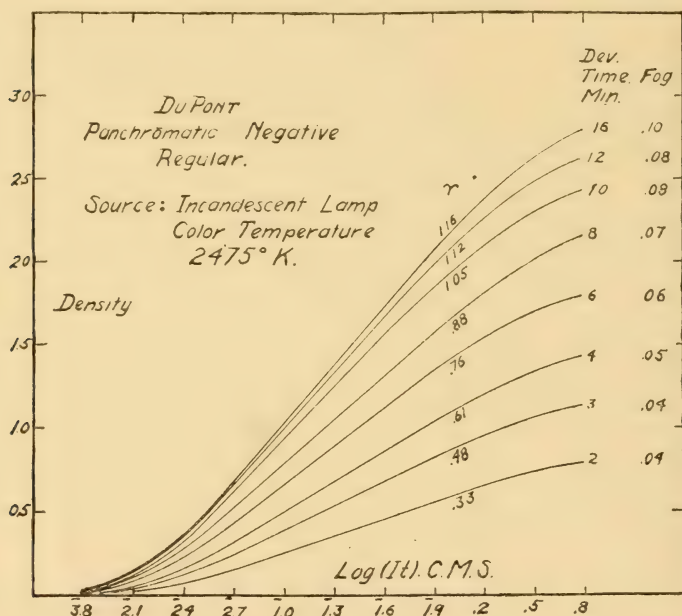


Fig. 2. Rate of development curves for Du Pont regular panchromatic negative.

would be obtained in some laboratories. Very similar curves would be obtained in any other satisfactory negative developer, although the time taken to reach any specified gamma would obviously depend upon the developer chosen, the temperature at which it was used, and the degree of agitation during development.

The two families of curves in Fig. 1 and Fig. 2 show that both films are capable of producing gammas somewhat higher than unity, thus having potential contrast-giving possibilities beyond the normal requirements for negatives produced under present practices.

The greater densities produced on the special negative by corresponding exposures and developments of the two films show the greater speed of this special stock. To present this more clearly, Fig. 3 shows the curves for 6 minutes' development plotted together.

The gamma values taken from the curves of Fig. 1 and Fig. 2 are plotted together against the time of development in Fig. 4. Since the two sets of points fall so close together, only one curve was drawn to represent the time-gamma relationship. This curve represents the time-gamma relationship for only one developer and one set of de-

veloping conditions, but no large difference in the time-gamma curves for the two stocks is to be expected in any commercial negative developer.

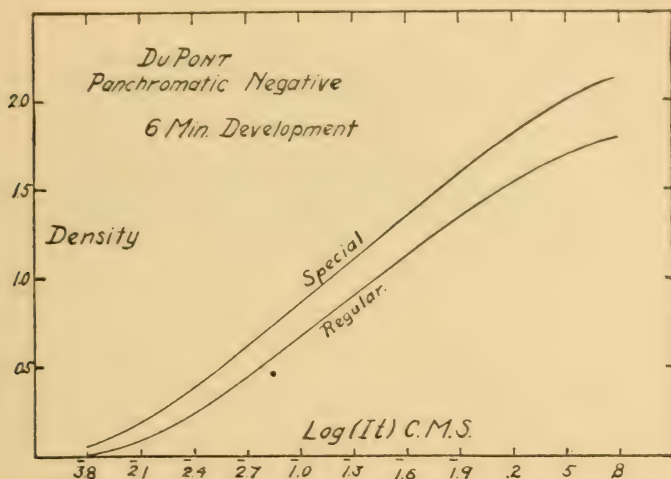


Fig. 3. H & D curves of Du Pont panchromatic negative.

Color Sensitivity

The completeness of the color sensitivity of these two films may be seen from the spectrograms shown in Fig. 5. Spectrogram A is for the special negative and spectrogram B for the regular film. These spectrograms were made on a small Hilger grating spectrograph, using a ribbon filament lamp as the source, with a neutral wedge over the slit, and do not readily yield quantitative data as to speed or contrast

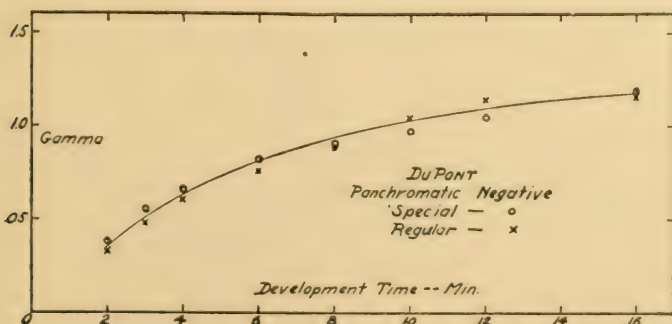


Fig. 4. Time-gamma curve for Du Pont panchromatic negative.

values. The source used, an incandescent lamp, emphasizes the red end of the spectrum in proportion to its importance for photography with sets lighted by incandescent lamps. From the point of view of over-all film speed the blue is relatively more important and the red relatively less so, when pictures are taken in sunlight.

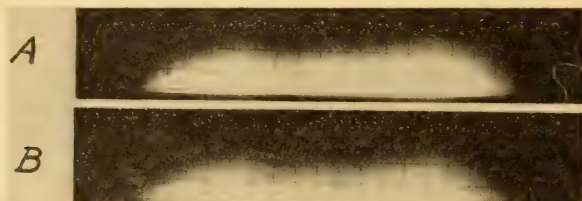


Fig. 5. Spectrograms on Du Pont special (A) and regular (B) panchromatic negatives.

Further information concerning the color sensitivity of the two films may be obtained by a study of the curves shown in Fig. 6. Here the curves marked "White" represent the density *vs.* log *E* relation for the unscreened incandescent lamp, which was operating as usual, at a color temperature of 2475°K. In this plot, *E* is expressed in arbitrary units as only relative values are of interest here. The curves marked "Red" represent the results obtained when this light was screened with a Wratten A filter. Similarly the curves marked

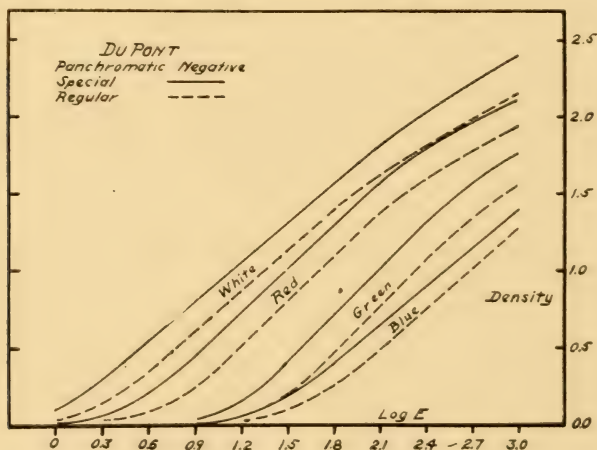


Fig. 6. H & D curves on Du Pont panchromatic negative, exposed to light as indicated below.

White: unscreened incandescent lamp operating at color temperature of 2475°K.; red: screened by Wratten A filter; green: screened by Wratten B filter; blue: screened by Wratten C filter.

"Green" and "Blue" show the data obtained with the B and C filters, respectively. It is interesting to note that the red filter transmits 40 to 45 per cent of the light photographically effective on either stock, while the green filter transmits only about 9 per cent and the blue filter about 5 per cent of such effective light. Of course, it must be borne in mind that these filters are not equally transparent at their points of maximum transmission, but these data serve to emphasize the importance of the red in photography with incandescent lamps. The fact that all four pairs of curves labeled White, Red, Green, and Blue, respectively, have the same separation between the numbers of the pairs shows that the relative color sensitivity of the two films is the same. The spectrograms of Fig. 5 indicated qualitatively this fact which now appears quantitatively.

The filter factors for these films were determined by independent experiments and confirm the conclusion just drawn. These filter factors, for sunlight, are given in Table I. It should always be borne

Table I

Filter factors for the Wratten filters, designated by letter, for sunlit scenes, for both Du Pont special and regular panchromatic negatives.

<i>Filter</i>	<i>Filter Factor</i>
K ₁	2.2
K ₂	3.1
K ₃	4
G	5
F	10
A	7
B	16
C	12

in mind when considering such factors that the specification of the source is as necessary as the specification of the filter and the film. Hence, these values cannot be considered as highly precise since the specification "sunlight" itself is rather indefinite. However, experience has indicated that these factors are quite satisfactory for these films under normal sunlight conditions.

Other Data

Photomicrographs of the individual grains in these emulsions are shown in Fig. 7. Fig. 7A is a photograph of the grains of the special emulsion and Fig. 7B of the regular emulsion. Both photographs were taken at the same magnification. Since it is not the individual grains but, in general, clumps of grains that produce the graininess of pictures as viewed on the screen, the curve of Fig. 8 is of more value than the photomicrographs in comparing the two emulsions. The unit of graininess is arbitrary, but if some standard is chosen relative values may be determined. Various instruments have been constructed to make such determinations. The results presented were obtained with an instrument designed by Conklin.² No significant difference in graininess appears between the two films, although the graininess of both is a function of the density, as appears from the curve.

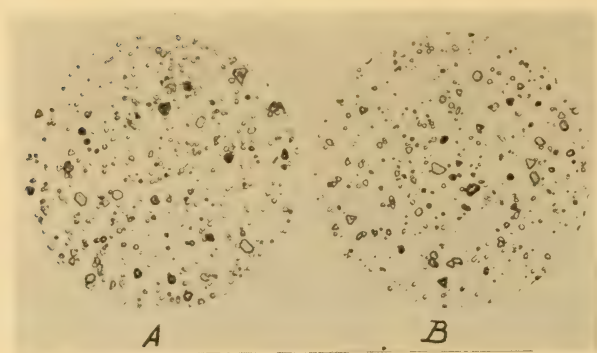


Fig. 7. Photomicrographs of the silver halide grains of Du Pont special (A) and regular (B) panchromatic negatives.

Closely allied with the graininess of the emulsion is its resolving power. This was determined for both emulsions by photographing a test object consisting of groups of parallel lines. This object showed great contrast between its dense and transparent portions.



Fig. 8. Density-graininess relation for both Du Pont panchromatic negatives.

The development of the negatives was carried to a gamma of 0.8. Under these conditions the special and the regular negatives both resolved 38 to 41 lines per mm.

References

- ¹ Moyse, H. W., and White, D. R.: *Trans. Soc. Mot. Pict. Eng.*, XIII (May, 1929), No. 38, p. 445.
- ² Conklin, O. E.: *J. Soc. Mot. Pict. Eng.*, XVI (February, 1931) p. 159

THE MOTION PICTURE INDUSTRY AND THE SCHOOL

*William F. Kruse**

TOO often, in analyzing the market prospects and the trend of developments in the motion picture industry, attention is centered so strongly on the theatrical screen that other important fields are all but overlooked. It is true that the bulk of the industry's product now finds its market in the theatre, and that whatever money is being made comes in mainly through the box-office windows. There are other markets, however, that are taking on more and more importance, and manufacturers and producers are looking ahead to those fields with increasing interest.

Foremost in the non-theatrical field stands the school. Properly speaking, the American school is not merely an institution, it is an industry, one of the largest in the land. The schools rank sixth among America's "20 Giants of Industry" in point of investments, and first in expenditures for building operations. They have been climbing steadily as the depression has forced other branches of industry to allow their building operations to decline; in 1929 schools were third, in 1930 second, in 1931 first. Six and three-quarter billion dollars in property owned, an average of two and a half billion dollars spent annually for upkeep! Here is a market distributed over 240,146 separate school units housing, for at least part of every school day, one-fifth of the entire population of the country—a market involving the daily requirements of almost thirty million people.

Our cousins of the radio industry are fully awake to the importance of this market. Manufacturers sponsor various "Schools of the Air", organize conferences on uses of radio in schools, build "committees" and organizations of various types for the promotion of education by radio. Good results are being obtained. There is greater noise made about the use of radio in the schools than about the use of motion pictures, notwithstanding that the latter have had an acknowledged but thus far extremely humble place in the schools for more than twenty years. There is no conflict between the use of these two most modern of educational tools; on the contrary, they supplement and support one another and will work together admirably just as soon as the technique of radio education becomes somewhat more standardized and the methods of co-ordination of oral and visual teaching are worked out. What we aim to suggest in this article is, on the one hand, the importance of the school as a market for the motion picture industry and, on the other, the important social contributions in the field of public education that have been made and are being made by the motion picture industry.

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Value of Motion Pictures Admitted

There is no longer any debate in educational circles as to the value of the film as a teaching tool. This is important progress; twenty years, even five years ago, the story was a different one. Careful, scientifically-controlled tests by earnest scholars have determined that on almost every subject in the curriculum, pupils enjoying access to proper teaching films will make from 5% to 33% greater gains than equally intelligent children with access to all other means of teaching, excepting only the film. These tests have shown, furthermore, that with the aid of the film the average or even dull child can equal the work of the brightest, when the latter is deprived of film. We should be chary of rushing into high-sounding percentage figures in stating the claims of the motion picture as an educator. Figures never lie, but—they are often misunderstood and misapplied. Data, too, can be based on insufficient experimental material not adequately compared and controlled. This invariably draws resentment from the serious visual educator whose efforts are the principal means of extending the use of motion pictures and other visual aids in the schools.

More than ten years ago successive experiments at Columbia University in teaching "film" and "no-film" classes in geography showed greater gains of 32%, 53% and 21% in favor of the "film" groups. In 1923 at the University of Iowa, the James experiments indicated a gain in geography teaching of 16% over the oral lecture method; in 1925 the Skinner-Rich experiment in the New York Junior High Schools indicated a gain of 25% over the text-book alone; in 1928 the more extensive Freeman-Wood test covering over 11,000 children in twelve cities indicated an 18% greater gain. Approximately the same gain (19%) was registered in history teaching in experiments with fifteen seventh and eighth grade classes in New Haven, in a carefully checked and controlled test, conducted by Dr. D. C. Knowlton, of Yale. Not only is more learned, but more is remembered, according to these tests.

The film, furthermore, is a faster teacher. In an experiment of limited extent in Detroit in 1919, a class using a health and hygiene film for a 15 minute period made 5% better test records than another class receiving only oral instruction for a 55 minute period. The same type of subject, tried out simultaneously in three widely separated cities, indicated that a film group given 40% less teaching time than a non-film group got identical test records, while still another film group which had been given 70% less teaching time, scored only 7% lower final marks. In the New Haven history tests the experimental (film) group progressed 40 weeks, according to the Van Wagenen scale, as compared to the control (non-film) group's 38.5%.

These figures are merely cited to indicate the trend of the findings of qualified investigators on this field. Such findings have not always been uniform, that is no more than to be expected, since conditions in the schools, ability of the teachers, effectiveness of scientific control, and quality of the films have not been uniform. Occasion-

ally investigators, one in particular, have even found other methods, such as slides or chalk talks, to rank higher than film, but these experiments reveal important weaknesses, or are too limited to be of general application.

Dept. of Commerce Gives Findings

Extremely valuable is the result of a recent survey questionnaire sent by the U. S. Department of Commerce to 25,000 schools, with the collaboration of the U. S. Commissioner of Education. The teachers, reporting in detail on more than forty-four thousand film showings, give their endorsement to the following advantages resulting from the use of classroom films, and by the majorities indicated:

- (a) "An increased interest in school work and sustained interest in the topics studied"; 99 % affirmative.
- (b) "Quickened originality and larger participation in project work and other self activities"; 83 % affirmative.
- (c) "Greater desire and ability to discuss subjects"; 98 % affirmative.
- (d) "Increase in quantity and improvement in quality of the material read"; 81 % affirmative.
- (e) "Clearer appreciation of the richness, accuracy and meaningfulness of personal experiences"; 94 % affirmative.
- (f) "Greater facility in correlating features of their lessons with community conditions"; 93 % affirmative.
- (g) "Contribution to life experiences difficult and often impossible to secure by any other method"; 96 % affirmative.
- (h) "Marked improvement in range and accuracy of vocabulary"; 66 % affirmative.
- (i) "Ability to concentrate mental activities, think more accurately, and reason more soundly"; 81 % affirmative.

This favorable attitude on the part of the school world toward the motion picture has by no means always prevailed. In former days the educator complained vigorously against the quality of films and projection equipment made available to the school; the theatrical interests in turn protested against the type of use to which motion pictures were at first put in the schools. Solid grounds existed for both complaints. Until such time as the schools became at least a self-supporting if not profitable market, much of the film material available to the schools represented only theatrical cast-offs, the same was quite generally true of early school projection equipment, of which the less said the better. Naturally, the schools resented the "poor-relation" role into which they felt themselves forced, and many a pedagogic kick in the shins directed toward the theatrical film industry may have had its source in a sort of inferiority complex developed among customers on the non-theatrical field, notably the school and the church. On the other hand, the earlier use of the motion picture in the schools generally took the form of turning the rent-free school auditorium into a cut-rate theatre. This made the local theatre-owner unhappy, and also gave a solid foundation to pedagogic criticism of the film in general on the ground of lack of

correlation to studies, superficiality of impression, absence of grading, and in general, serving as distraction rather than concentration, entertainment rather than education.

So serious a problem, causing friction and antagonism between two major industries which ought to be working closely together for mutual interests, required a radical solution. The remedy was found in the absolute divorce of the classroom and the theatre, both with regard to contents of film material and to the very nature of the projection equipment used. Like many married couples, once separated, they found themselves the best of friends.

Today, the classroom teaching film, almost entirely 16 mm. safety film, bear more relation to the textbook than to the theatre; this tendency of closer correlation to standard textbooks and less reliance on theatrical precepts is gaining ground, with good results to both school and theatre. The trend of development on this question is best illustrated in the annual "Blue Book of the Non-Theatrical Screen". Up until its Sixth Edition (1929) no special section had been devoted to 16 mm. films. In that edition 485 films were listed as available only in 16 mm. while another 300 were noted as being available in both 16 and 35 mm. The following year there were 605 in the "16 mm. Special Section", and 700 additional available in both widths. The forthcoming (Eighth) edition will carry over 750 in the "16 mm. only" classification, and an additional 850 or more available in both. The "35 mm. only" sources have remained virtually stationary, numbering 1409 titles in the seventh edition. We may draw the conclusion that while even only 5 years ago almost all film was "35 mm. only", practically all subjects suitable for school use produced since then have been made available in both film widths. This increase has been supplemented by older 35 mm. pictures only recently re-edited for 16 mm. versions, and more especially by considerable numbers of strictly teaching films produced exclusively in 16 mm. for classroom use.

Meeting Classroom Requirements

The Bell & Howell Company, part of the warp and woof of the professional industry almost since the first crank was turned, gave heed to the requirements of the school, as a special field with special problems, just as soon as the visual educator had become articulate to the point of definitely formulating his grievances. Teachers were consulted to get first-hand reaction from the classroom; film laboratories and industrialists who had been furnishing films to schools were likewise drawn upon for suggestions. The definite adoption of 16 mm. film as an exclusively safety standard finally cleared the way for vigorous definite action.

The first Filmo projector put on the market offered a solution to the basic problems that had stood in the way of classroom movies. It used non-flammable film only, hence fire hazard was out. Its operation technique was so simplified that a ten year child could run it—leaving the teacher free at the screen to explain the lesson as it was projected, in a sort of personalized "talkie" accompaniment. It

was extremely light in weight, hence could be readily carried by woman or child, from room to room as required. It was jointed so as to provide instant adjustment of the screen image for height, eliminating the pile of books and chalk-boxes previously kept on hand for levelling of slide and opaque projectors. Projection lenses were instantly interchangeable so as to give any desired screen image size regardless of room dimensions.

No time was wasted in senseless controversy with the advocates of the projected still picture. Its high value in the teaching of all subjects involving static concepts was not only instantly conceded, but acted upon—the movie projector was designed so that a “still” could be projected from any single frame, when desired, and should the point of stoppage be inadvertently passed, the machine would reverse instantly and without getting out of frame. Framing presented no problem other than extreme precision in manufacture, since the 16 mm. film, born at a time when the motion picture industry had already become mechanically standardized, faced no chaos of frame lines. Therefore, a projector made with adequate precision of film movement would be automatic in its framing.

In a school projector the question of film movement is of even greater importance, if such a thing is possible, than in the theatre. One of the heaviest indictments against the early school movies was their unsteadiness and flicker on the screen. This indictment was only too often based on solid fact, and the fear of excessive eye-strain to their students held back many teachers from installing motion picture projectors. Here, then, was one of the obstacles that the motion picture engineer had to overcome, and this was done by transferring to the humble school projector an efficiency of design and precision of manufacture hitherto associated only with Bell & Howell standard cinemachinery. On the heart-shaped cam that actuates the shuttle-tooth, a tolerance limitation all ways, of one-half of one-thousandth part of an inch is maintained, permitting the use of a shuttle tooth that just fills the perforation, and assuring an undeviating cycle of operations to effect a precise film movement. This means long life to film as well as steady pictures. Furthermore, lateral registration and additional steadiness at the aperture is obtained by a unique system of side tension.

A New Auditorium Problem

The availability of this type of projection equipment changed the attitude of thousands of educators who had hitherto been cold to the arguments put forward on behalf of the motion picture. One argument still remained—admitting that the projector manufacturer had licked the problem of classroom movies, how about the auditorium? A 16 mm. machine of sufficient power for auditorium showings was demanded—and supplied. It was found, too, that many classrooms could not be made absolutely dark, and even where a school went to the expense of recessed opaque shades to effect Stygian darkness, the resultant ill effect on class discipline made it a doubtful gain. So the wattage of the projector lamps climbed slowly from 165 to 200, then

to 250, and now to 375. What the end will be no one who knows the limitless change of the motion picture industry will venture to prophesy. Another important contribution to the auditorium solution is in the development of more efficient projection lenses, such as the new Cooke 3" F 2.5 and 4" F 2.8. The present light takes care of audiences of 2000 if need be, has shown satisfactory pictures 16 feet wide with projection throws of better than 150 feet, and will cut through the residual light in any partially shaded classroom where sunlight does not fall directly on the screen.

Each new development in the industry as a whole has been made available to the schools in a modified version. Kodacolor has been used effectively; its spread is served materially by the new lamps, and as soon as other color processes become available in 16 mm. width their welcome on the school field is assured.

Enter, the Talkies

So, too, with the talkies. In the Spring of 1929 we were able to offer the National Education Association the first portable classroom 16 mm. talkie equipment. By June we presented the next meeting at Columbus, Ohio, with a talkie invitation from their absent Past-President, Frank Cody, Superintendent of Schools of Detroit, calling upon all teachers to come to Detroit for the next meeting. It was a dramatic moment in the Senate Chamber, at the State Capitol, when the head of Birmingham schools, Superintendent Glenn, introduced as the first speaker a man who was several hundred miles away! A switch was pressed, the screen lit up, an unseen band played, and Frank Cody, true to life and with all his charm of mannerism, appeared to assure prospective visitors that he would show them Detroit's schools and parks, and would promise not to show them its jails.

In 1929, the talkies were rather "high-hatted" at the Atlantic City Convention of the N. E. A. In 1931, at Detroit and Los Angeles, they occupied the center of the stage among the things that are to come. In answer to the misgivings about sources of 16 mm. talkies we can point to more than 200 subjects already available, many of them real teaching films prepared under the direct editorship of leading American educators. This is a very different situation from the old days, when the schools, like mistreated step-children, had to take whatever was too old or too bad (or sometimes too good) for the theatre.

Getting School Acceptance for the Talkie

It is not to be expected that educators as one man will rise to acclaim the talkie and to introduce it into their schoolrooms. Many, even of those who endorse silent films wholeheartedly, are still sceptical of whether the added advantages of the sound accompaniment will not be more than offset by its disadvantages, pedagogical and financial. We are definitely committed to the school "talkie", but practically all of the teachers still have to be shown. By perfecting our Filmophone equipment, by making available a wealth of really

worth-while educational talkies, by drawing in on their preparation the services of authoritative educators as done by Ufa, Pathe and Erpi, and by staging such surprisingly successful publicity stunts as Harley Clarke's recent Washington "test", we will speed up this process a good deal.

Our reference to this "test" is by no means intended as disparagement. By getting the approval of President Hoover, and the co-operation of Commissioner Cooper and his staff, Mr. Clarke guaranteed a favorable press throughout the country for the finding that his group of talkies had contributed 38% added gain in knowledge of subjects which were supposed to have been previously taught in public schools. That the test involved less than 100 children, arbitrarily



The Bell & Howell Filmophone presenting a sound film entertainment in a schoolroom.

selected and "tested" in anything but normal classroom conditions, and that no control groups existed to provide comparison with other methods of teaching the same subjects, are a few of the weak spots that any educator will be quick to recognize. It is quite likely that, as the reports maintain, talkies will prove twice as beneficial as silent films, but it will take more than this comparison with Dr. Knowlton's registry of 19% gain due to silent films to prove it. Only when we have talkie experiments conducted with the same scientific method and safeguards, and on somewhat the same extent that characterized the Yale experiment, will there be proper basis for comparison. As publicity that will waken many a mind to the value of school films, however, it would be difficult to find anything to equal this excellent piece of work.

There is every reason to assume that a properly prepared teaching talkie film should score even higher gains than an equally good silent film. We look for the educational world to convince itself of this right speedily, by means of scientifically controlled experiments. As far back as 1923, we found F. D. and H. Y. McCluskey reporting, on the basis of experiments in Cleveland and Chicago schools, that 18% superior results were obtained when the teacher gave a talk explaining a film while it was being shown, than when the film was shown alone. In 1923 in Detroit an experiment to test the effect of musical accompaniment to an informational film resulted in the finding that the music contributed heavily to attentiveness, and possibly also slightly to additional gains. We cannot allot to the talkie, however, every gain contributed by a teacher's personal talk. In some cases the gain will be less, in others more, depending on the personal equation, the quality of the film in content, recording and reproduction, as well as on the relative authority and personality of the personal and the screen instructors, etc. Carefully controlled experiments should give data on these questions valuable to both school and motion picture industry.

Same Cycle of Development

Development on the school talkie field has paralleled that of the silent picture twenty years ago, but the cycle has been travelled much more rapidly. The initial idea of transplanting the sound theatre bodily to the school auditorium as a complete cure-all has already been abandoned, and all producers now recognize that to crack the school market with talkies they will have to work with 16 mm. They are doing this today, leaving the 35 mm. quasi-professional equipment to its rightful place in the larger auditorium, where a theatrical situation prevails. In adapting the talkie to the classroom, however, it is up to the manufacturer to learn what the teacher really requires, then work out the answer. One of the objections to sound is that a recorded lesson deprives the teacher of psychological control of the class while the lesson is in progress. We have solved this by introducing a microphone through which the teacher can interpolate his own remarks during the lesson, his voice coming from the loud-speaker precisely as does the recorded matter, therefore not distracting attention from the audio-visual impression delivered from the screen.

The advent of sound actually terrified many teachers who had previously invested heavily in silent projection apparatus. The fear of obsolescence was strong upon them, and was only removed when we were able to demonstrate that even the earliest of Filmo projectors, used daily by schools for the past seven years, could readily be adapted for use with the Filmophone, as well as for every other advance registered by the motion picture industry (color, more powerful illumination, etc.). A policy of guarding against obsolescence is important in developing the confidence of the educators in the broadening of their motion picture work.

The Movie Camera also Serves School Needs

Everything that has been said about projection equipment also applies to the camera. The 16 mm. amateur camera has opened wide the gates to the schools to make their own films at relatively low cost, and many are taking advantage of it. Their demands on this field become more and more exacting, and it will not be long before almost our whole bag of professional tricks will be in use by the advanced amateur. Of course this will not be allowed to deprive the basic amateur camera of its phenomenal simplicity. But various improvements, such as seven speeds, three-lens turret and critical focuser, and accessories like filters, masks, vignettters, all-steel tripod and alignment gauge are enabling the clever amateur to turn out some remarkable photography.

There will always be problems to solve and differences to adjust between two such giants of industry as the motion picture and the school. The relationship between the two is closer and more cordial today than at any time in the past, and this relationship is growing still closer on the basis of collaboration in work. Once we have come to a clear understanding of two facts—first, that here are two distinctly separate fields, and second, that the school is a new market plenty big enough to justify effort and funds that may be spent in its development—much greater progress is assured. Educational organizations like the National Education Association, the National Congress of Parent-Teacher Associations, women's clubs, etc., are taking increasing interest in school movies, this interest taking on more and more definite organizational form. Manufacturers and producers are working closer than ever with schoolmen, and in such important organizations as the "National Academy of Visual Instruction" meet with the educator on a common footing. All this is travel in the right direction.

The school looks to our industry as a powerful ally and aid in its tasks. The industry may well look to the school as a market that may some day surpass the theatre itself in importance.



Desert Study

Ned Van Buren, A.S.C.

PROJECTION ARCS*

*A. C. Downes and W. C. Kalb***

IN THE early years of the motion picture industry large size, low intensity carbons were used for light projection in theatres. Since then the low intensity lamps using large size carbons have been almost entirely replaced by the low intensity reflecting arc lamps, the high intensity reflecting arc lamps, and the high intensity condenser type lamps. In the last few years the need for more light even in the smaller theatres has been augmented by various factors such as the use of perforated sound screens, colored films, and the demand for a higher level of general illumination.

Carbon manufacturers have endeavored to aid the situation in the smaller theatres by recently developing low intensity reflecting arc carbons which carry higher currents than those previously available. It is believed that data on the characteristics of these carbons and their application to projection problems may suggest ways to improve still further the illumination of the screen.

The current carrying capacities of these carbons are given in Table I. Approximately 2 amperes have been allowed as a factor of safety

TABLE I.

Current Ratings of S. R. A. Positive Carbons

Carbon Diameter	Minimum Recommended Current	Maximum Recommended Current	Current Above Which There is Constant Sputtering
10 mm.	21	24	25
12 mm.	28	32	34
13 mm.	32	42	44
14 mm.	42	52	55

between the maximum current and the extreme upper limit of the carbons. Data on the 10 and 14 mm. carbons have been included although there has up to this time been no active demand by the industry for these sizes. If the carbons are burned above their maximum current, the light will be unsteady and there will be no appreciable gain in candle-power. If the carbons are burned below the minimum current the efficiency of light production is decreased and the arc tends to become unsteady because the crater area is too small to sufficiently cover the end of the carbon.

It is the light from the crater of the positive carbon which is of value. The light from the negative carbon and arc stream is only approximately 10 per cent of the total light and cannot be utilized for projection purposes. The diameter of the positive crater increases with increasing current. The data in Table II illustrate the change for these particular carbons.

* A resume of recent papers presented before the S.M.P.E.

** National Carbon Company

TABLE II.

Change in Crater Diameter with Current S. R. A. Positive Carbons

Carbon Diameter	Current	Crater Diameter In Inches
10 mm.	21	.262
10 mm.	24	.278
12 mm.	28	.311
12 mm.	31	.325
12 mm.	34	.344
13 mm.	34	.347
13 mm.	40	.378
13 mm.	44	.392
14 mm.	44	.404
14 mm.	50	.419
14 mm.	55	.432

The action of the direct current on the crater of the positive carbon heats it to approximately 4000°K. , the vaporizing temperature of carbon. This gives the crater an intrinsic brilliancy of 130 to 180 candles per square millimeter, which is exceeded only by the crater of a high intensity carbon.

As shown in Fig. 1, the intrinsic brilliancy is uniform on the core, rises sharply to a maximum on the shell just outside the core, and

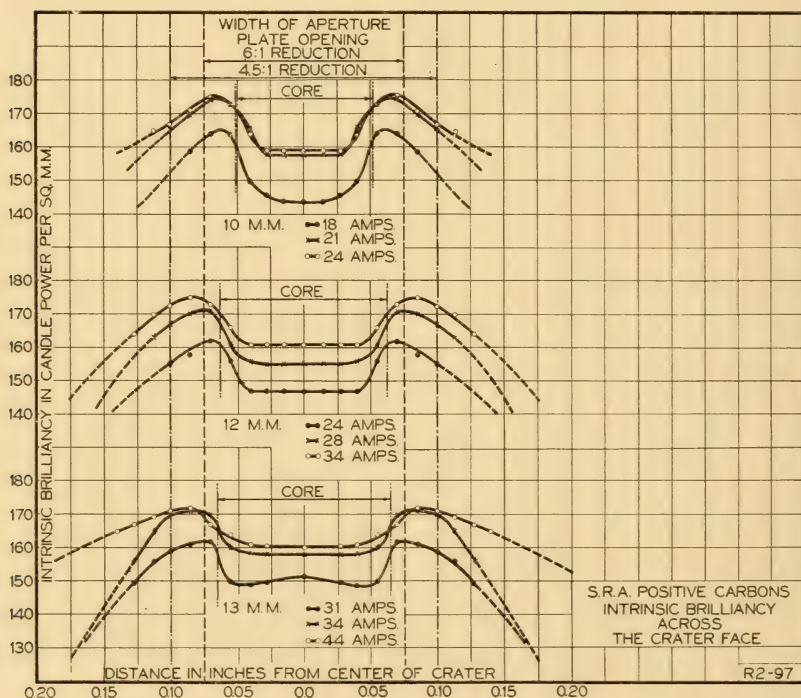


Fig. 1. Variation of intrinsic brilliancy of the positive crater.

decreases again near the edge of the crater. If the carbon were solid instead of cored, there would be no dip in the intrinsic brilliancy at the center of the crater. However, the core is necessary to furnish arc-supporting materials and to maintain the crater position constant with respect to the carbon. Without it, the current would have to be reduced materially and the crater would travel around the end of the carbon resulting in a very unsteady light on the screen.

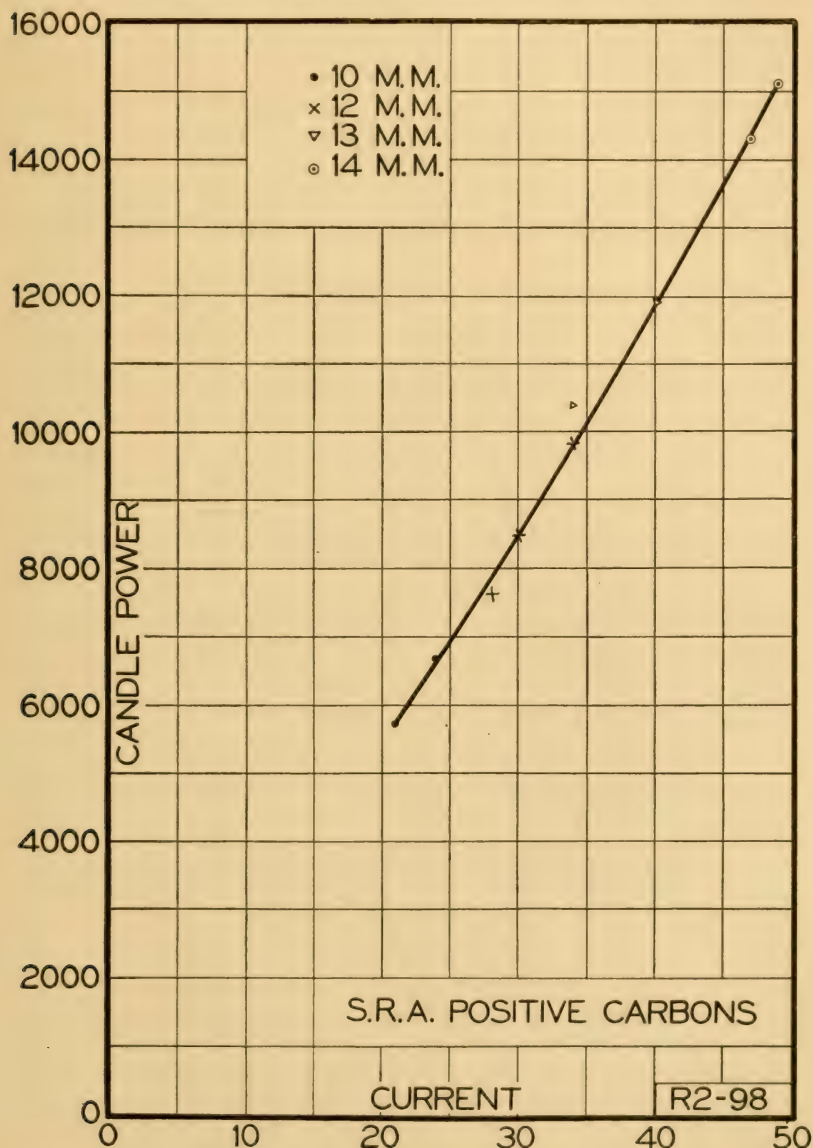


Fig. 2. Variation of candle-power of the crater with respect to the current.

It should be noted that above a certain current for each size carbon there is practically no increase in the intrinsic brilliancy of the central part of the crater—merely an increase in crater size and intrinsic brilliancy near the edges of the crater. It is also evident that after this critical current has been reached the intrinsic brilliancy is the same for the central position of the crater on a 10 mm. carbon as for the 13 mm. carbon. This important characteristic will be referred to later in relation to the optical system. The approximate current at which the central portion of the crater reaches its maximum is the minimum recommended current in Table I.

The candle-power of the crater from a point directly in front is shown in Fig. 2 for various values of arc current.

Of more importance for projection than the candle-power directly in front of the crater, however, is the light distribution about the crater. Polar candle-power curves for two currents are given in Fig. 3.

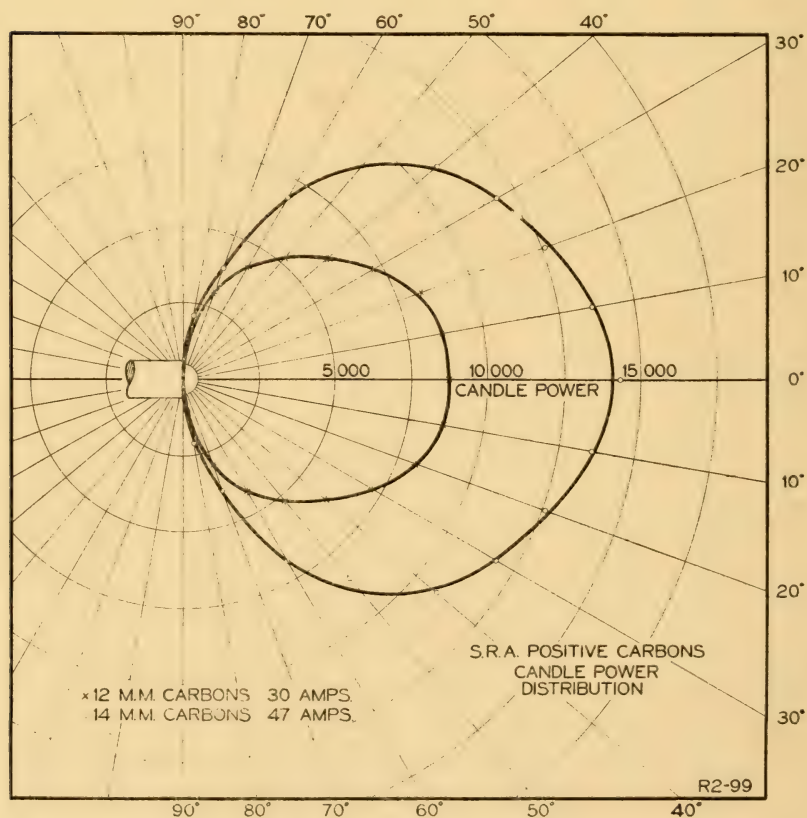


Fig. 3. Polar candle-power curves showing light distribution about the crater.

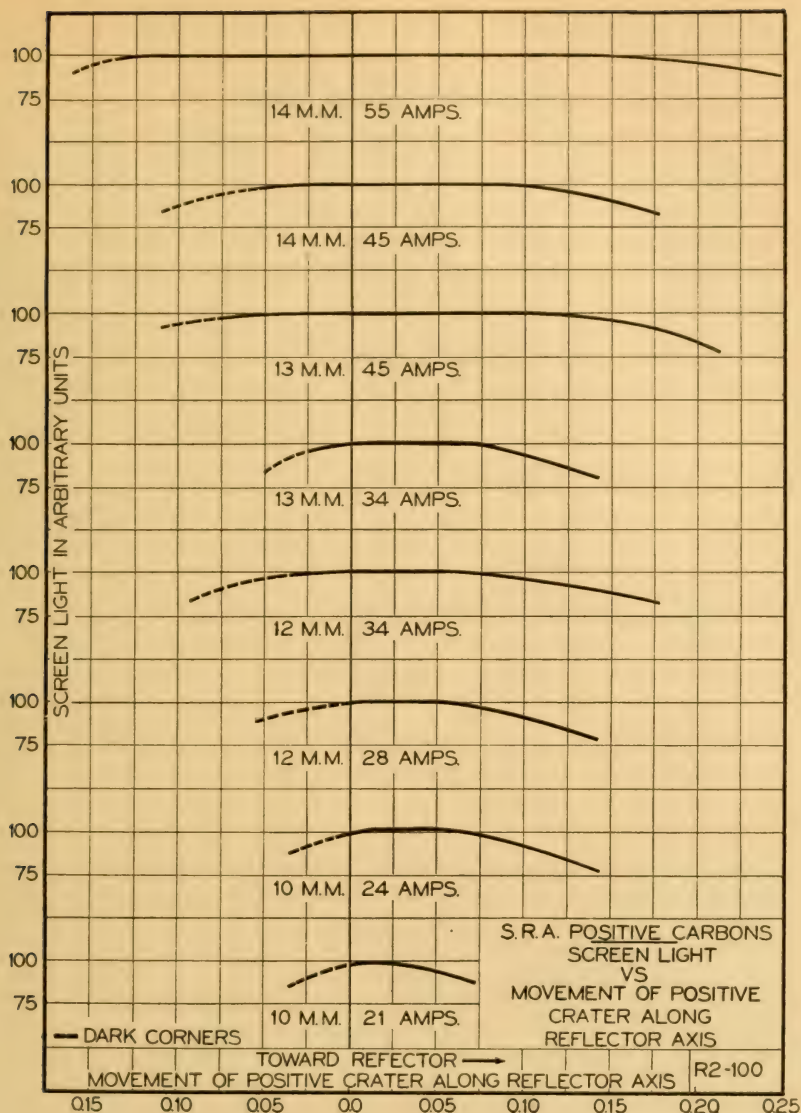


Fig. 4 Change in light on screen with respect to movement of positive carbon along the reflector axis.

The polar curves for other currents and carbon sizes would be similar in shape and proportional to the candle power values in Fig 2. These polar curves are misleading if they are not carefully analyzed. A better method of expressing the same thing is to compute the quantity of light in each angular segment. These values as well as the total quantity of light and the cumulative percentages are given in Table III.

TABLE III.

S. R. A. Positive Carbons Angular Light Distribution
12 Millimeter Carbon at 30 Amperes

Angle	Av. Cp.	Lumens Light Flux in Various Zones	Per Cent of Total Lumens	Cumulative Per Cent of Total Lumens
0-10	8695	825	3	3
10-20	8360	2360	9	12
20-30	7590	3520	13	25
30-40	6670	4180	16	41
40-50	5730	4430	17	58
50-60	4730	4230	16	74
60-70	3600	3570	14	88
70-80	2220	2260	9	97
80-90	720	780	3	100

26,155 (Total Lumens)

14 Millimeter Carbon at 47 Amperes

Angle	Av. Cp.	Lumens Light Flux in Various Zones	Per Cent of Total Lumens	Cumulative Per Cent of Total Lumens
0-10	13,950	1320	3	3
10-20	13,100	3700	9	12
20-30	12,200	5600	14	26
30-40	11,350	7130	17	43
40-50	9650	7460	18	61
50-60	7630	6850	16	77
60-70	5340	5300	13	90
70-80	2930	3100	7	97
80-90	1015	1110	3	100

41,570 (Total Lumens)

The optical systems commonly employed in the present low intensity reflecting arc lamps use a parabolic reflector with a condensing lens or an elliptical reflector alone. Irrespective of the system used, the light pick-up from the arc has usually been a cone of 120 degree opening which, according to Table III, would include approximately 75 per cent of the light from the positive crater. The light gathered by the reflector is focused on the aperture plate in the form (neglecting spherical aberration) of an image of the crater. The magnification of the system is approximately 6 to 1. Under these conditions it is theoretically correct that the optical system is saturated when a current of 21 amperes is used on the proper size carbon and the higher currents merely give more light to be absorbed or reflected from the aperture plate. It can be seen that this is plausible by a reconsideration of Fig. 1. In this figure, instead of projecting the crater face onto the aperture plate, the width of the aperture plate opening with the proper reduction for 6 to 1 magnification has been projected back onto the crater. The values of intrinsic brilliancy for the portions of the craters within the aperture plate width indicate that no more light could be expected to go through the aperture plate from a 13 mm. carbon at 44 amperes than from a

10 mm. carbon at 21 amperes. They also show that if the carbon is run below its rating, for example, 31 amperes on a 13 mm. carbon or 24 amperes on a 12 mm. carbon, there will be less light through the aperture plate opening because of the lower intrinsic brilliancy of the middle portion of the crater.

However, there are very important reasons for not using, for ordinary theatre projection, the smallest size carbons or the lowest current theoretically possible. The total light and the uniformity of the light on the screen depend largely on the position of the positive crater with respect to the focal point of the mirror. In practical projection it is very difficult to hold the positive crater within 0.025 inch of the correct focal point. This accuracy would be necessary to obtain the maximum screen light from a 10 mm. carbon at 21 amperes with a mirror arc system in common use.

The change in the light on the screen with the movement of the positive carbon along the axis of the reflector of a typical optical system for various currents and sizes of carbons is shown in Fig. 4 and Table IV. The movement of the crater away from the axis for

TABLE IV.

S. R. A. Positive Carbons Extent of Movement of Positive Crater along Axis without Materially Decreasing Screen Light

Carbon Diameter	Current	Total Allowable Movement in Inches along Axis for a Change of No More than 5 Per Cent in Screen Illumination
10 mm.	21	.06
10 mm.	24	.10
12 mm.	28	.10
12 mm.	34	.15
13 mm.	34	.11
13 mm.	45	.21
14 mm.	45	.18
14 mm.	55	.34

the various carbon sizes and currents without a material decrease in the screen light was not measured, but is illustrated in Fig. 1 and Fig. 5, where the aperture plate opening for a 6 to 1 magnification is compared with the crater diameters and intrinsic brilliancies. These data show the disadvantage of using a carbon below, or even near, its minimum current capacity rather than the next lowest size carbon near its maximum current capacity.

From these considerations, the use of a 13 mm. carbon at 40 amperes appears to be amply justified to guarantee uniformity of screen illumination. Even with this carbon and current, the positive crater must be held within 0.07 inch of the focal point of the reflector to maintain the screen illumination within 5 per cent of the possible maximum.

The limitations of the low intensity mirror arc optical systems heretofore available have been clearly defined. The fastest projection lens would pass a cone of light only approximately 20 degrees in total angular diameter. This practically fixed the magnification ratio of the reflector system at 6 to 1 and the angle of light taken by the reflector from the crater at 120 degrees. If the angle of the reflector were increased to take a greater angle of light from the

crater, this additional light could not be passed by the projection lens. If the magnification were reduced there would be no advantage because the angle of divergence beyond the aperture plate would be increased and the projection lens could pass only a correspondingly smaller proportion of the light picked up by the reflector.

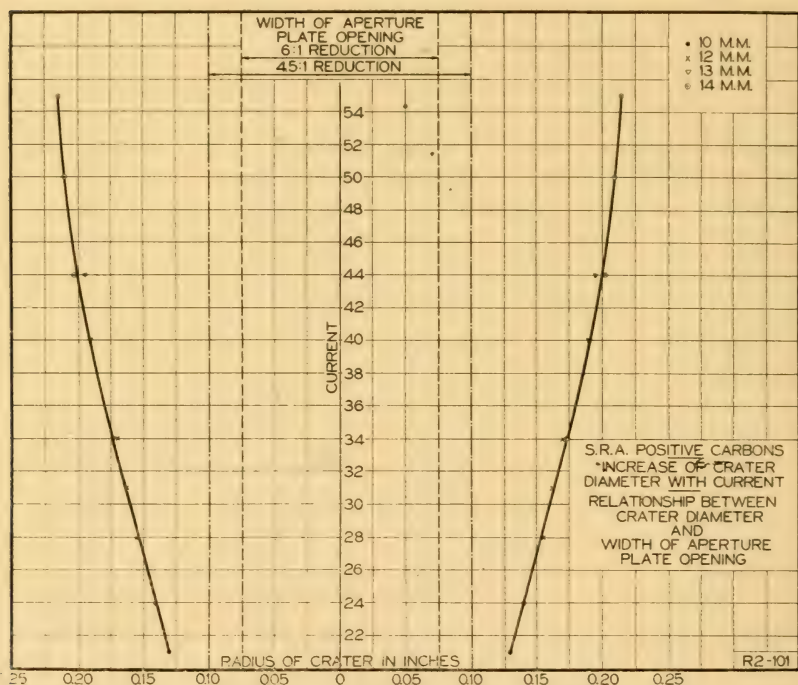


Fig. 5. Relation between crater radius and current.

Recently, however, projection lenses have been made available which will pass a cone of light approximately 29 degrees in total angular diameter. Such a lens will allow the magnification to be reduced from 6 to 4.5 and still take all the light from a reflector with a gathering angle of 120 degrees about the positive crater. This change would merely require a new reflector of the proper magnification, (possibly slightly larger in diameter and further from the arc to allow sufficient room in front of the lamp) the new type projection lens, and the proper carbons and current. The light on the screen would theoretically be increased inversely as the square of the magnification or approximately 75 per cent over that now available. A comparison of the relative sizes of the crater and aperture plate with the two magnifications is given in Fig. 1 and Fig. 5. It appears that an increase of only 10 amperes in the arc current over that used for the 6 to 1 magnification would give the corresponding flexibility and evenness of screen illumination to the 4.5 to 1 magnification. For example, a 14 mm. carbon at 50 amperes with the

new magnification of 4.5 to 1 would have the same allowable movement around the focal point of the reflector for good screen illumination as a 13 mm. carbon at 40 amperes with the 6 to 1 magnification.

Recent changes which have been made and rumors of others about to occur in the motion picture industry have again emphasized the constant demand for more light on the screen of the theatre. At the present time only the high intensity arc can furnish the light concentration necessary to satisfy the demands of the larger theatres. It therefore seems desirable to call attention to certain characteristics of high intensity arcs which may help in the solution of the ever present problem of increasing the useful light.

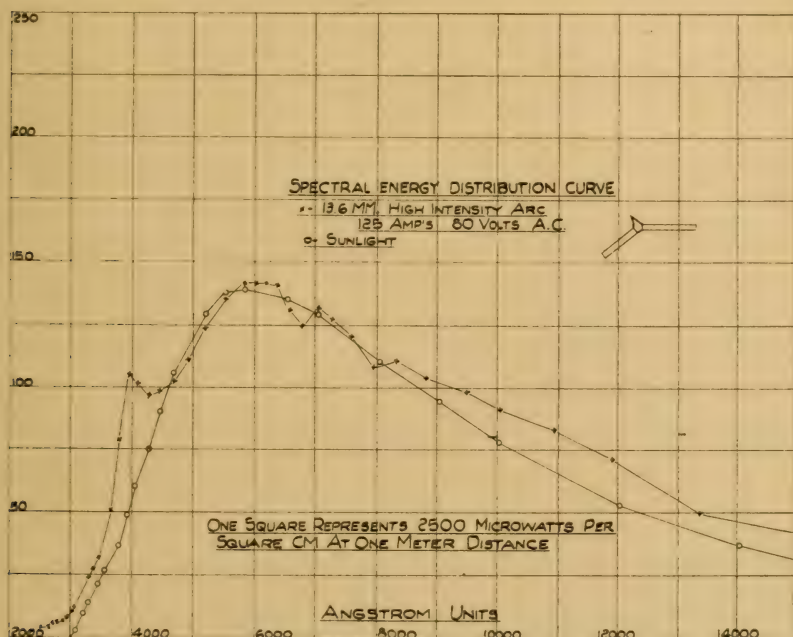


Fig. 6.

The light from a high intensity arc emanates from two distinct sources, the crater and the tail flame. The tail flame produces about thirty per cent of the total light from this type of arc but is of no value for projection because it cannot be focused on account of its large size, shape, and position. Therefore, in a consideration of the characteristics of the high intensity arc only the crater light should be studied. The characteristics should include candle power both directly in front of the arc and at various angles, the area of crater opening, intrinsic brilliancy, and spectral energy distribution for the various carbon sizes and operating currents.

Figure 6 shows the energy distribution curve for a typical high-intensity carbon arc such as is used in motion-picture projection and photography. On this is superposed the energy distribution curve

for normal sunlight. The radiation from the arc as measured is the radiation from the positive crater only, as in most applications of this type of light source this is all that can be utilized. The curve shows the rather striking agreement between this light source and natural sunlight through the entire range of the spectrum.

The candle power of the crater light directly in front of the arc is shown in Fig. 7.

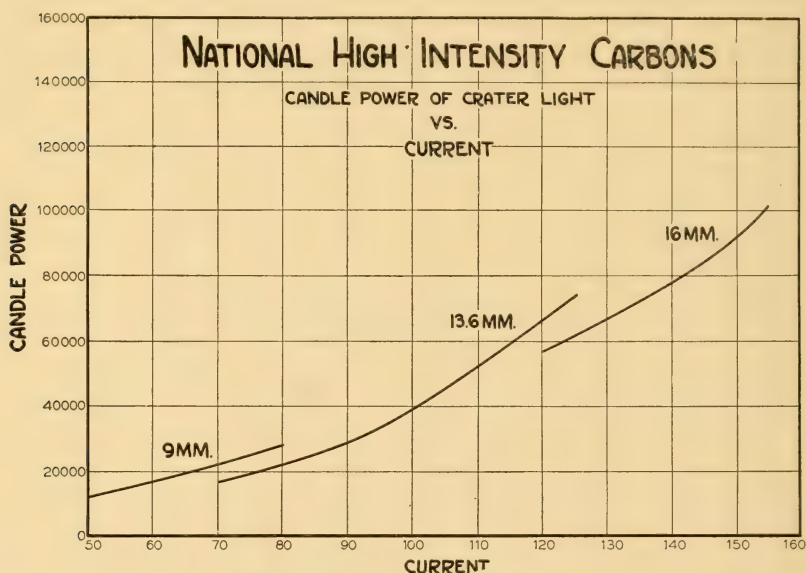


Fig. 7. Candle power of crater light vs. current.

As would be expected the candle power increases with the current. When the same current is used on two different size carbons of the same composition, the small size carbon, that is, the one with the higher current concentration, gives the greater candle power.

The crater light is only approximately 68 per cent of the total light from the high intensity arc as measured directly in front of the crater. The additional light comes almost entirely from the tail flame which streams out of the positive crater.

The areas of the crater openings of the different size carbons at the various currents are given in Fig. 8.

The cross sectional areas of the 9 mm., 13.6 mm. and 16 mm. high intensity carbons are 64 sq. mm., 145 sq. mm., and 201 sq. mm., respectively. It is obvious from the curves that the crater openings for even the higher currents are much less than the original carbon cross section.

The decrease in crater opening for the lower current densities is due in part to the increased spindle or tapering of the portion of the carbon projecting from the positive holder. This increased tapering is

due to the enormous decrease in the length of carbon consumed per unit of time for a small decrease in current which allows a longer time for the hot surface of the carbon close to the crater to burn away.

The size of the crater opening or light source of the high intensity carbons is important in considering the application of any optical system for it has long been recognized and clearly demonstrated that the light efficiency for motion picture projection decreases rapidly as the area of the light source increases.

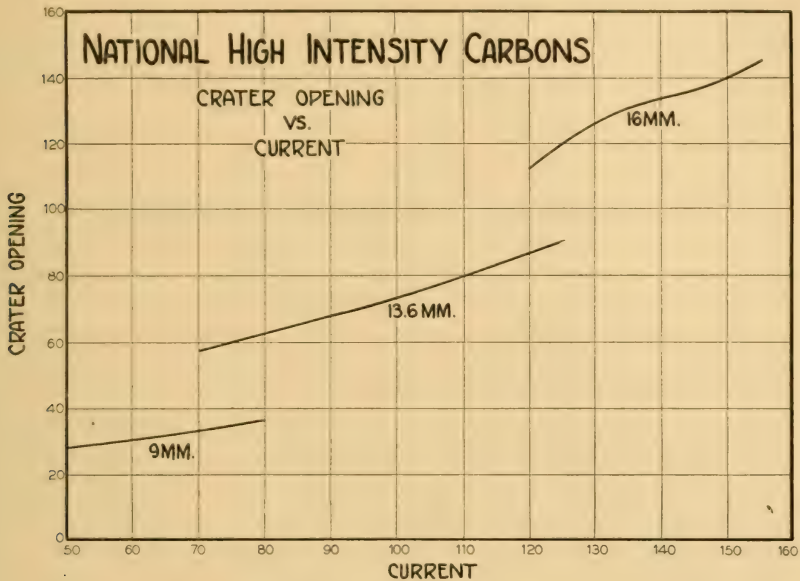


Fig. 8. Crater opening vs. current.

The intrinsic brilliancies in candle power per square millimeter of crater opening are plotted in Fig. 9.

As in the case of the candle power, the intrinsic brilliancy increases very rapidly as the current is increased on any given size carbon. It is interesting to note that practically the same intrinsic brilliancies are obtained with the various sizes of carbons at the currents ordinarily used. These values, ranging from 500 to 750 candle power per square millimeter, illustrate quite forcibly the advantage that the high intensity arc has for projection purposes over the plain carbon arc with an intrinsic brilliancy of 130 candle power per square millimeter and the incandescent tungsten filament projector lamp run at overvoltage with an intrinsic brilliancy of 27 candle power per square millimeter.

An example of the use that can be made of data of this nature is furnished by comparing the relative light which can be obtained on the screen when 13.6 and 16 millimeter carbons are used with the ordinary plano-convex lens combination. If the 13.6 millimeter carbons were to be burned at 120 amperes and the 16 millimeter

carbons at 145 amperes, the crater areas (Fig. 8) are 90 and 137 square millimeters and the intrinsic brilliancies (Fig. 9) are 737 and 620 candle power per square millimeter, respectively. It has been shown that for crater areas of 137 square millimeters the relative screen illumination with arc and lenses set properly is approximately 27 per cent more than for a crater area of 90 square millimeters with two sources of the same intrinsic brilliancy. After correcting for the difference in intrinsic brilliancy, it is found that only 7 per cent more light can be expected from the 16 millimeter carbons at 145 amperes than from the 13.6 millimeter carbons at 120 amperes. Such calculations as these, which are made possible in part by the data given above, should be of some assistance in the more efficient use of this very fine source of light for projection of all kinds.

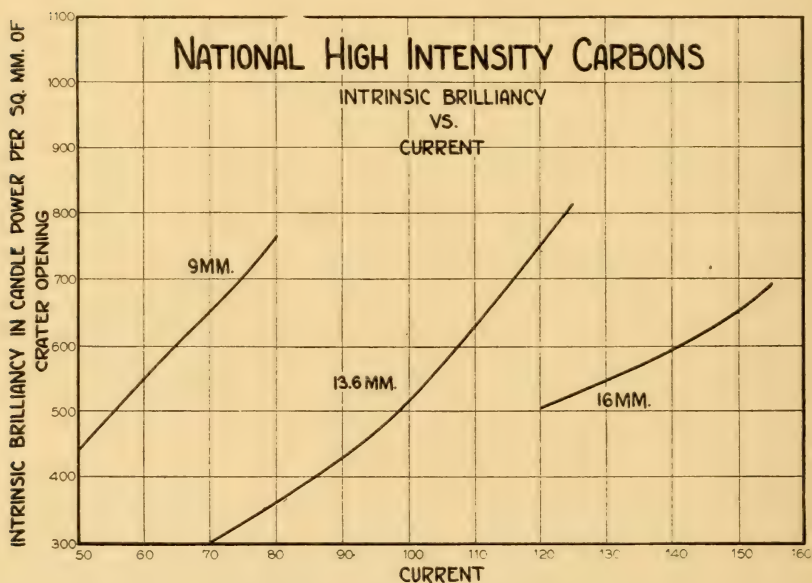


Fig. 9. Intrinsic brilliancy vs. current.

In most commercial lamps the angle formed by the axis of the two carbons is fixed. It is well known, however, that the relative position of the two carbons along their respective axes appreciably affects the behavior of the high intensity arc. The following discussion will show that rather minor variations in position have an unexpectedly large effect on the amount of light and the steadiness of the arc.

The results of these variations are common to all types of high intensity lamps and carbons but most of the observations here discussed, unless otherwise specified, were made on 13.6 positives with $\frac{3}{8}$ in. copper coated cored negative carbons at 120 amperes.

It has been the practice for carbon manufacturers to specify the current at which high intensity carbons of various sizes should be burned, but they have been reluctant to specify the voltage. A glance at Fig. 10 will explain the reason for this reticence.

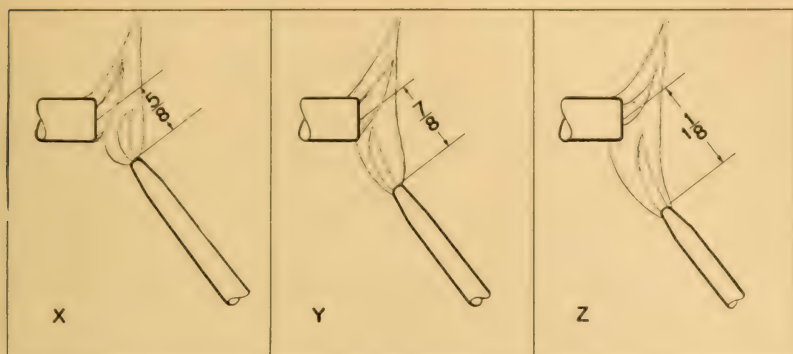


Fig. 10.

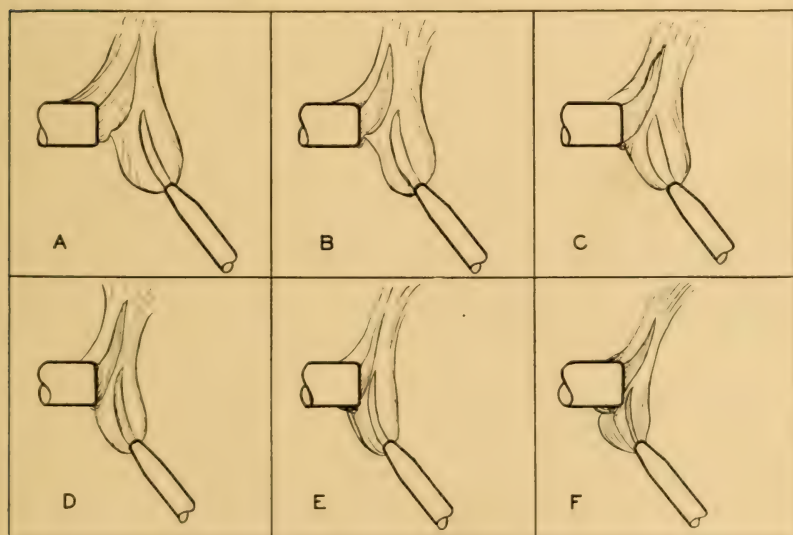


Fig. 11. 120-ampere arcs.

This figure gives graphic representations of three 70 volt arcs, but the arc lengths, measured as shown in the figure, vary from $1\frac{1}{8}$ in. to $\frac{5}{8}$ in. In X the negative flame does not touch the lower part of the positive carbon, in Y it just touches it, and in Z it overlaps it considerably. These arcs give entirely different results in quantity

and quality of crater light and the projectionist would only be confused by any voltage specification without qualification as to the relative position of positive and negative carbon and this latter relationship is probably more important than the arc voltage

The most practical means of studying the results of the movement of the positive carbon with respect to the negative is to hold the negative carbon tip in one position and move the positive carbon along its axis. Graphic representations of the arcs obtained at 120 amperes by moving the positive carbon successive steps of $\frac{1}{8}$ in. along the axis are given in Fig. 11.

The arc voltage for this particular set varies from 86 in position A to 55 volts in position F. The negative flame in position A in

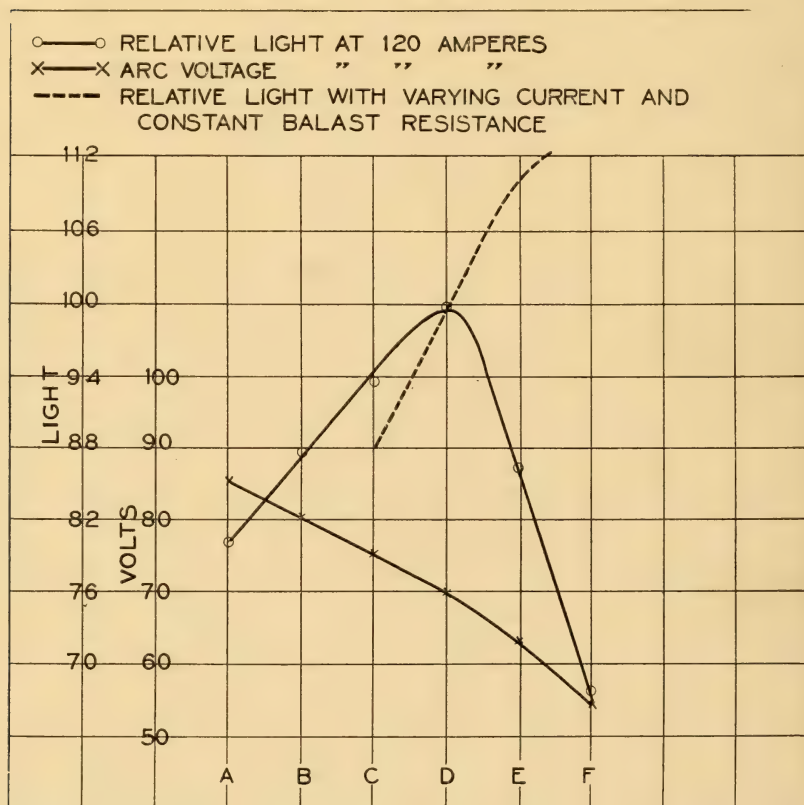


Fig. 12. Light intensity graph.

Fig. 11 is considerably ahead of the positive so that the positive flame actually rolls out of the bottom of the positive crater before the negative flame strikes it and diverts it upward. As the positive carbon is moved ahead this condition is altered so that at D the edge of the negative flame just touches the lower edge of the positive carbon and practically the whole negative flame is sweeping across

the crater opening as though compressing the positive flame. Finally at F a good portion of the negative flame plays against the bottom of the positive carbon and again only a part sweeps across the positive crater. The values of relative light and arc voltage for these different arcs at 120 amperes are shown in Fig. 12. The maximum useful light is obtained at position D (as would be expected from the above description of the action of the negative flame against the positive crater opening.) The light diminishes as the positive is moved in either direction from position D.

Unfortunately the position of maximum light is not the position of maximum steadiness. With the arc in position A, the direction of the positive flame from the crater is not stable, resulting in many large flickers in the crater or useful light. This condition is improved as the positive carbon is moved forward so that the large flickers decrease and are practically eliminated at positions C and D. In these positions small flickers of rather short duration are evident. The negative flame is either just hitting or just clearing the lower side of the positive carbon in these positions and tends to oscillate on and off the edge of the positive shell in a rapid movement causing medium size flickers of short duration.

When the positive has been advanced to position E in Fig. 11 the edge of the negative flame is permanently on the bottom side of the positive shell and the negative flame drives against the positive arc stream with a steady force of uniform direction and magnitude so that there is practically no flicker in the useful light from the arc. With the arc in this position, a high intensity spot lamp has been observed for half an hour at a time without detecting any noticeable flicker in the spot.

The light is lower as shown in Fig. 12 for this position than in position D where some flickering is obtained. The light is still lower in position F without any change in steadiness so that the position of optimum condition is that in which the edge of the negative flame impinges on the positive carbon as close to the end as possible without noticeable flickering on the screen or in the spotlight.

If the positive carbon is changed from C or D to that of E without changing the position of the negative or the ballast resistance, as is often done in the projection booth, there might actually be an increase in light with the elimination of practically all of the noticeable flicker. If the positive is moved in the opposite direction toward position A the decrease of light will be much greater than that shown in the solid line of Fig. 12. This change is shown by the dotted line in Fig. 12 for a 115 volt power line. The reason for this is obvious when the decrease of voltage in going from A to F is noted. If the ballast resistance and line voltage were kept constant, a movement of the positive from position A to any of the other positions would necessarily give an increase in current.

The distance from the projected axis of the positive carbon to the tip of the negative carbon for the arc illustrated in Fig. 11 is $\frac{5}{8}$ in. Similar experiments were made with distance of $\frac{1}{2}$ in. and $\frac{3}{4}$ in., with exactly the same results. Within these limits and with

the same relative position of the positive and negative flames the arc length had no noticeable effect on the useful light.

In the high intensity arc burning 16 mm. positives and 11 mm. plain cored negatives with an angle of 28 degrees between the carbon axes, it found similarly that the position of maximum light was not that of maximum steadiness and that the edge of the negative flame definitely bathed the lower edge of the positive carbon when the light was free from flickers.



ON THE THEORY OF TONE REPRODUCTION, WITH A GRAPHIC METHOD FOR THE SOLUTION OF PROBLEMS*

Loyd A. Jones, A. S. C. **

THE PROBLEM of ascertaining the exact extent to which it is possible by the photographic process to produce a pictorial representation of an object which will, when viewed, excite in the mind of the observer the same subjective impression as that produced by the image formed on the retina when the object itself is observed has engaged the attention of workers in the field of photography for many years. There are many phases of the subject to be considered, and a complete treatment requires a careful analysis of the various factors upon which depend the operation of our visual perception of space and spatial relations. A complete analysis, therefore, leads not only into the realm of physical science, but also into those of psychology and philosophy. It is not the purpose of this paper to present such a complete treatment, but to deal with a single phase of the subject.

A careful consideration of the various factors upon which depend our visual perception of space leads to the conclusion that brightness and brightness differences (*i. e.*, contrast) are by far the most important factors which are reproducible by the photographic process. The form factor (including size, shape, position, definition, *etc.*) to which so much importance is usually attached and which is conditioned by the performance of the image forming system, depends for its effectiveness upon the proper rendition of brightness differences. The proper reproduction of brightness and brightness differences, therefore, is of preëminent importance, and it is with this brightness factor and the possibility of its correct reproduction by the photographic process that this paper will deal.

This problem of tone reproduction, as it is commonly called, has frequently been regarded as requiring only the correct reproduction in the picture of the actual physical brightness of the original, and of the actual contrast relations existing between various areas of the object. When we consider, however, that a given brightness or contrast may produce an entirely different subjective impression, depending upon the state of adaptation of the observer's eye, it is obvious that such a treatment of the subject cannot afford a complete solution of the problem. The problem may, in fact, be divided into two general parts: the one, which we may term the objective phase, dealing with the reproduction of the actual physical brightnesses and capable of being completely solved by purely physical

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methods; the other, the subjective phase, including a consideration of those factors which determine the nature of the subjective impressions produced by the action of given physical stimuli under various conditions, and requiring the use of psycho-physical methods and data for its adequate treatment.

Simplifying Assumptions

In order to simplify the subject and bring it within the limits of a single paper, it will be necessary to make certain simplifying assumptions. Since the sensitivity of the photographic plate to radiation of different wave-lengths is in general radically different from that of the eye, objects in which color is present have not in general the same brightness when considered from the visual standpoint as when the evaluation is in terms of the photographic plate.

Let us, therefore, assume that all areas of the object considered are both visually and photographically non-selective (*i. e.*, colorless). Under such conditions values of visual brightness are directly proportional to photographic brightness. Thus, this treatment will deal with brightness relations uncomplicated by any consideration of selectivity. Let us assume further that all photographic deposits considered are also non-selective in order that visual and photographic density values may also be considered identical.

Terminology and Symbols

The problem to be treated involves so many operations, materials, and inter-relations that it is of considerable importance to adopt at the outset a logical system of terminology and symbols. The factors involved are:

	Symbol
1. Object.....	<i>O</i>
2. Negative sensitive material.....	<i>X</i>
3. Negative.....	<i>N</i>
4. Positive sensitive material.....	<i>Y</i>
5. Positive.....	<i>P</i>
6. Material reproduction.....	<i>MR</i>
7. Subjective reproduction.....	<i>SR</i>
8. Subjective object.....	<i>SO</i>

The first six of these are objective or physical in nature, the last two subjective or perceptual. An evaluation of *O* in terms of *MR* gives a function which defines the extent to which actual objective reproduction of brightness is obtained under the limiting conditions assumed, while an evaluation of *SO* in terms of *SR* gives the function required to determine the reproduction of the subjective impression.

The symbols as indicated will be used as subscript letters attached to the symbol for the various physical factors applying to them.

The physical factors are:

	Symbol
Radiant flux.....	<i>F</i>
Illumination.....	<i>I</i>
Brightness.....	<i>B</i>
Reflection coefficient.....	<i>R</i>
Transmission coefficient.....	<i>T</i>
Exposure.....	<i>E</i>
Time.....	<i>t</i>
Density.....	<i>D</i>

In Table I is given a schematic outline showing the various steps in the computation of the final result of a given tone reproduction problem. It will be noted that the process is divided into ten distinct steps, represented by the Roman numerals I to X. The necessary factors required at each step are designated by the corresponding arabic numerals. In the parentheses, designated by the letters *A*, *B*, *C*, etc., are statements either verbal or symbolic of the transformation factors which convert the factor of one step into that of the next succeeding step. At the starting point, I, it will be noted that the "subjective object" is taken, by which is meant the subjective impression of brightness and brightness difference excited in the mind of the observer. This impression, it is obvious, is that which it is desirable to reproduce rather than the actual physical brightness values which are measured by the usual physical methods. In practice, however, it is more convenient to take as the actual starting point of the operation the measured brightness values, B_o , of the object and to evaluate the subjective relation between B_o (II) and B_{so} (I) relative to that between B_{mr} (IX) and B_{sr} (X) after having obtained the necessary values of B_{mr} .

Table I.

- I. The Subjective object (SO).
 1. Subjective brightness of object (B_{so}).
 - A. (Adaptation level of observer when viewing object, A_o , $B_{so} = f(A_o)$.)
- II. Object (O).
 2. Brightness (B_o).
 - B. (The constant of the image forming system, K_x .)
- III. Image on the X (negative) material.
 3. Illumination (I_x) = $B_o \cdot K_x$.
 - C. (Exposure time, t_x .)
- IV. Exposure on the X (negative) material.
 4. Exposure $E_x = (I_x \cdot t_x)$.
 - D. (Development, fixing, washing, drying, intensification, reduction, etc. Specified by $D_n = f(E_x)$.)
- V. Negative (N).
 5. Density, D_n , or transmission, T_n .
 - E. (Illumination, I_n .)
- VI. Image on the Y (positive) material.
 6. Illumination, $I = (T_n \cdot I_n)$.
 - F. (Exposure (printing) time, t_y .)
- VII. Exposure on the Y (positive) material.
 7. Exposure $E_y = (I_y \cdot t_y)$.
 - G. (Development, washing, fixing, toning, etc. Specified by $D_p = f(E_y)$.)
- VIII. Positive (P).
 8. Reflecting power, R_p .
 - H. (Incident illumination, I_p .)
- IX. The material reproduction (MR).
 9. Brightness (B_{mr}) = $(R_p \cdot I_p)$.
 - I. (Adaptation level of observer, A_{mr} , $B = f(A_{mr})$.)
- X. The Subjective brightness (SR).
 10. Subjective brightness (B_{sr}).
 - J. (The relation between B_{sr} and B_{so} determines the extent to which the desired subjective impression of tone is accomplished. $B_{so} = f(B_{sr})$.)

The Necessary Data

Before considering the method of obtaining the tone reproduction solution, it will be well to consider briefly the individual groups of data which must be utilized. These may be summarized as follows:

1. Relative to the observer: A_o , adaptation level of eye when observing the object.
2. Relative to the object: B_o , brightness values for various areas of the object.
3. Relative to image forming system: K_x , factor converting B_o to I_x .
4. Relative to negative material: $D = f(E)$, the H and D curve of the material.
5. Relative to printing system: I_n , illumination incident on negative during printing.
6. Relative to positive material: $D = f(E)$, the H and D curve of the material.
7. Relative to material (objective) reproduction: I_{mr} , illumination on the print during observation.
8. Relative to the observer: A_{mr} , adaptation level of the eye while observing the reproduction.

A Graphic Solution

The graphic solution is presented in Fig. 1, the necessary curves being plotted in the four quadrants designated for reference as *I*, *II*, *III*, and *IX*. For convenience in plotting a double scale along the OX' axis, a separation between the upper and lower quadrants is made, the two points designated by O being, in fact, identical.

Along the line OX is established a suitable logarithmic scale upon which may be plotted the logarithms of the brightness values for the various areas of the object. Let the points a_o , b_o , and c_o represent three typical object-brightness (B_o) values, a being the lowest and c the highest which exist in the object considered. After having located on this scale ($\log B_o$) the various points representing the brightness values of the object which it is desired to reproduce, the curve A is plotted directly under the $\log B_o$ scale, and properly placed in the horizontal direction relative to the points on the $\log B_o$ scale. This curve A is the characteristic H and D curve of the sensitive material on which negative is made. It must be determined by sensitometric methods such that it is a true representation of the characteristic of the negative material when used under the conditions existing in the making of the negative, such conditions including those factors operative in transforming the latent into a real image as well as the necessary physical condition relative to quality and intensity of the exposing radiation. Curve A is plotted with values of log exposure as abscissas and densities as ordinates, the $\log E_x$ scale being laid off on the line Y' , $Y'X$, and the density scale on the $Y'X$, X .

The density values for the negative include the density of both fog and supporting material as well as of the silver deposit due to the exposure, thus being values of total density. Since the assumption has been made that the deposits are non-selective, it follows that the color-coefficient is unity. It was assumed that the density values are determined under such conditions of illumina-

tion (diffuse or specular) that they are true values for the printing process used, contact, or projection as the case may be. The unit interval on the $\log E_x$ scale must be equal to the unit used in establishing the $\log B_0$ and equal also to the unit interval of all log-scales used throughout the solution. The adjustment of the scale of $\log E_x$ along the line Y' , $Y'X$, depends upon the choice of the negative density value (D_n) by which it is desired to render a given object brightness. For instance, if it be desired to render point a_0 , the lowest brightness in the object by a negative density of 0.20, the scale of $\log E_x$ is so adjusted that when curve $\bar{A}$ is plotted the perpendicular dropped from point A will cut the curve at a density value of 0.20.

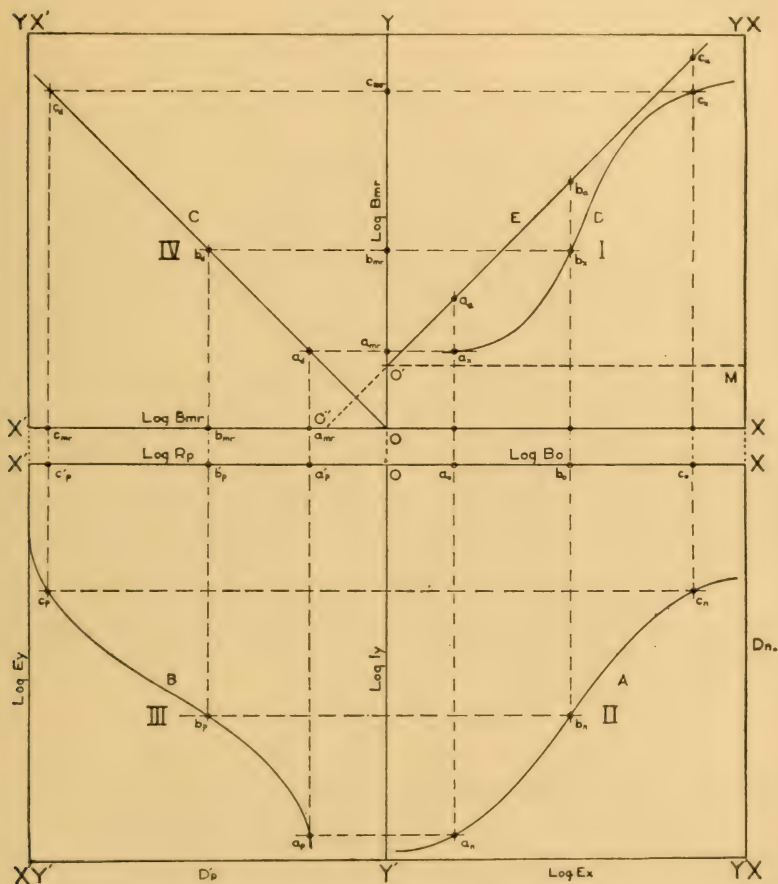


Fig. 1. Graphic solution for the objective phase of toric reproduction.

The relation between the $\log B_0$ and the $\log E_x$ scale will now determine the exposure that must be given to the sensitive material on which the negative is to be made in order to obtain the rendition of

the chosen brightness value by the desired negative density. In order to compute the exposure time t_x , however, certain constants of the image forming system used in imaging the object on the sensitive material must be known.

Let the constant K_x be defined as the value by which a given value of object brightness B_o must be multiplied in order to obtain the value of the illumination I_x incident on the negative material at the point where the particular area of object is imaged. K_x is, therefore, the value which satisfies the equation.

$$\begin{aligned} B_o K_x &= I_x \\ \frac{E_x}{I_x} &= t_x \\ \therefore t_x &= \frac{E_x}{B_o K_x}, \text{ or} \\ \log t_x &= \log E_x - (\log B_o + \log K_x) \end{aligned}$$

In order to compute t_x (K_x being known), it is necessary only to read the values of $\log B_o$ and $\log E_x$ at the points where any line parallel to OY cuts the two scales, and substitute in the equation.

The value of the constant K_x depends on several factors such as diameter of stop, object and image distances, spectral transmission of the lens material, *etc.* The evaluation of K_x in terms of these various factors is somewhat complex, and will not be considered at this time.

It is convenient to regard the negative produced by the development of the exposed sensitive material (X) as a means of impressing a series of various exposures upon this sensitive material (Y) upon which the positive or print is to be made. The D_o scale must, therefore, be transformed into an inverse scale giving the relative values of the various illuminations which the negative will allow to act upon the material Y during the printing operation. Let I_n be the illumination incident upon the negative during printing and I_y the illumination transmitted by the negative and therefore incident upon the positive material Y . Let T_n be the transmission coefficient of the negative. T is related to D (density) by the equation:

$$D = \log \frac{I}{T}$$

and T is defined by the equation,

$$T = \frac{I_1}{I_0}$$

where I_0 = the incident illumination; I_1 = the transmitted illumination.

Hence:

$$\begin{aligned} I_y &= I_n T_n \\ \log I_y &= \log I_n + \log T_n \\ &= I_n - D_n \end{aligned}$$

Since I_n is a constant, differentiation gives $d \log I_y = - d D_n$. Hence, any interval on the $\log I_y$ scale is numerically equal to the corresponding interval on the D_n scale but of opposite sign. Now along the line OY' establish a $\log$ scale on which the value of I_y computed from the known values of D_n and some suitably chosen value of I_n may be plotted.

In quadrant III, plot curve B , the characteristic curve of the positive material (Y). This also must be determined under conditions which give the true characteristics of the material as used in making the print from the negative. The abscissa values of this curve are the densities D'_p while the ordinates are the corresponding exposure values plotted on the scale of $\log E_y$ established in a suitable position on the line $X', X'Y'$. The scale of $\log E_y$ must be so adjusted along the line $X', X'Y'$ that the curve B , when plotted, will occupy the proper position in the vertical direction relative to the position of curve A . The proper position of curve B is determined by deciding by what value of D'_p it is desired to render some chosen value of D_n . For instance, let it be required to render the highest brightness, c_0 , of the object by a just perceptible density on the positive. Assuming that the resulting print is to be viewed with an illumination such that the eye is operating in the region of maximum sensitiveness to brightness difference, a deposit differing in brightness by 2 per cent from the background will be just perceptible. This is equivalent to a transmission or reflection coefficient of 98 per cent, which corresponds to a density of approximately 0.008. In order to fulfill the requirement it will be necessary to adjust the scale of $\log E$ so that when the curve B is plotted, a horizontal line drawn through the point where $D'_p = 0.008$ will cut curve A at c_0 , which is also the point where a perpendicular dropped from c_0 cuts curve A_y . The relation between the values of $\log E_y$ and $\log I_y$ at the points where any line parallel to $X'O$ cuts the two scales determines the exposure necessary to obtain the desired result. Thus:

$$\frac{E_y}{I_y} = t_y$$

$$\text{or } \log t_y = \log E_y - \log I_y$$

Substituting in this equation the values of I_y and E_y , the value of t_y , the exposure time necessary, may be determined.

It will be remembered that in order to establish the scale of $\log I_y$, a value of I_n was assumed. Since an arbitrary choice of this value without previous knowledge of the speed of the positive material Y may lead to inconvenient or absurd values of t_y , it may be more logical to omit the establishment of the I_y scale and take the relative value of $\log E_y$ and D_n at the points where any horizontal line cuts the respective scales as a means of determining the exposure necessary in making the positive.

Thus:

$$\log t_y = \log E_y - \log I_y$$

but

$$\log I_y = \log I_0 - D_n,$$

therefore,

$$\log t_y = \log E_y - \log I_0 + D_n$$

The corresponding values of $\log E_y$ and D_n having been determined, two variables, I_0 and t_y , remain, and by choosing a convenient value of t_y the value of I_0 (the illumination incident on the negative during printing) necessary to satisfy the equation may be found.

Now let the points a_p , b_p , and c_p be located on curve B at the points where horizontal lines passing through the points a_n , b_n , and c_n intersect curve B , the points a_n , b_n , and c_n having been located at the intersections of curve A with perpendiculars dropped from points a_o , b_o , and c_o .

Along the line OX' lay off a log scale opposite in direction to the scale of $\log B_o$. The scale OX' is that from which the reflection coefficient (R_p) (or transmission coefficient T_p) of the various areas of the positive are determined. The position of this scale along the line OX' is determined by consideration of the values on the D'_p scale and the reflection or transmission coefficient of an area of the positive which has received no exposure. Let R_b (or T_b) be the reflection coefficient of such an area.

The values of D'_p are derived from the measurement of the reflection or transmission coefficient of the various areas of the positive relative to the reflection or transmission coefficients of an unexposed area of the positive material which has received, of course, the same development treatment as the other areas of the positive. These values, therefore, are of relative reflection (or transmission) coefficients. This method of measuring and specifying positive densities is preferable (especially in the case of positives to be viewed by reflected light) from the standpoint of practice, and is the usual procedure in the sensitometry of positive materials. But in order to find the brightness of the various areas of the positive, when observed under a given condition of illumination, it is necessary to know their absolute reflection coefficients. It is necessary, therefore, in order that the values of R_p (or T_p) read from the $\log R_p$ scale may be in absolute terms and suitable for the computation of resulting brightness values (B_{mf}) to lay off the values of this scale ($\log R_p$) so as to include the factor R_b (or T_b). The relation between the relative and absolute reflection (or transmission) coefficients is given by

$$R'_p \cdot R_b = R_p$$

or

$$\log R'_p + \log R_b = \log R_p$$

Where R'_p is defined by the equation

$$\begin{aligned} \log R'_p &= -D'_p \\ \therefore \log R_p &= +\log R_b - D'_p \end{aligned}$$

The scale on OX' must therefore be so constructed that at corresponding points on the $\log R_p$ and $\log D'_p$ scales the relation between the values of R_p and D'_p shall be as indicated in this equation.

This equation for the case of a positive material on a transparent base and intended to be observed by transmitted light becomes

$$\log T_p = +\log T_b - D'_p$$

In such cases it is sometimes more convenient to measure the values of D'_p in absolute terms, that is, they already include density of the unexposed area. The term T_b , therefore, becomes unity, making $\log T_b$ zero and the relation is expressed simply as

$$\log T_p = -D'_p$$

Now the points a'_p , b'_p , and c'_p are located on the $\log R_p$ scale at the intersections of the perpendiculars through the points a_p , b_p and c_p , with the line OX' .

The values read from the scale at these points (a'_p , b'_p , and c'_p) are the reflection (or transmission) coefficients of the areas on the positive by which the areas of the object represented by the points a_o , b_o , and c_o are rendered.

The brightness (B) of a surface in terms of its reflection coefficient (R) and the incident illumination (I) is given by the relation

$$\begin{aligned} B &= I.R \\ \log B &= \log I + \log R \end{aligned}$$

Assuming then that the illumination on the positive during observation is I_p , the brightness of any given area of the material (objective) reproduction is obtained by the relation

$$\log B_{mr} = \log R_p + \log I_p$$

The brightness of the areas a'_p , b'_p , and c'_p can, therefore, be computed for any assumed value of the illumination under which the positive is observed or the value of I_p can be computed for any assumed brightness for a given area. On the line OX' establish a $\log$ scale such that for corresponding points on this and the $\log R_p$ scale (b'_p and b_{mr} , for instance) the values of $\log B_{mr}$ and $\log R_p$ will with the assumed value of I_p satisfy the equation

$$\log B_{mr} = \log R_p + \log I_p$$

Or, if it is desired that any given area of the positive be of the same brightness as the corresponding area of the object, the value of I_p necessary can be computed by the relation

$$\begin{aligned} \log B_o &= \log B_{mr} = \log R_p + \log I_p \\ \log I_p &= \log B_o - \log R_p \end{aligned}$$

where $\log B_o$ and $\log R_p$ are the values for corresponding points or object and positive, such as, for instance b_o and b'_p . Since the relation between the reflection coefficient of the various areas of the positive may be entirely different from the relation between the brightness values of the corresponding areas of the object, it is in general possible to realize this equality of brightness condition for only one point on the positive. In practice, however, it is found that by proper adjustment of conditions it can be realized throughout a finite range, which in some cases is a considerable proportion of the entire tonal range of the object.

Now in considering the extent to which a given positive observed under given illumination reproduces the subjective impression caused by observation of the object itself, it is necessary to take into account the state of adaptation of the observer's eye not only while viewing the reproduction, but also when looking at the object. The curve which determines the relation between what we shall term the material reproduction and the subjective reproduction is, in the complete graphic solution, plotted in quadrant *IV*, and is referred to as the subjective relative-contrast function. In order to avoid confusion, it will be well for the present to omit consideration of this step in the problem and to complete the first solution for material reproduction, after which a more comprehensible exposition of the subjective phase will be possible.

In order to obtain the reproduction curve, it is necessary to transfer the points a_{mr} , b_{mr} , and c_{mr} to the OY axis. This can be done by rotating the $\log B_r$ scale about the point O until it coincides with the line OY , but, since later a curve (the subjective relative-contrast function) will occupy quadrant *IV*, it will be better to make use of what may be termed a "dummy" curve (C) in *IV*, this being simply a line making an angle of 45° with the line OX' and passing through O . Vertical lines through the points a_{mr} , b_{mr} , and c_{mr} intersecting curve D locate the points a_a , b_a , and c_a on this curve and horizontal lines through these intersections locate, by their intersection with the line OY , the position of points a_{mr} , b_{mr} , and c_{mr} on this scale. Now the intersections of the horizontal lines through a_{mr} , b_{mr} , and c_{mr} (on line OY) with the vertical lines through a_o , b_o , and c_o determine the points a_x , b_x , and c_x which, when connected as shown, established the shape and position of the reproduction curve D (in *I*). This affords a graphic representation of the relation between the brightness factors of the object and those of the material reproduction (the illuminated positive). Now, through the point on the $\log B_{mr}$ scale (on line OY) where $\log B_{mr}$ is equal to the value of $\log B_o$ read at the point O (on line OX) draw a line parallel to OX . In the figure this is represented by the broken line $O'M$. This line is the absolute x axis of the reproduction curve D while the line $O'Y$ is the corresponding y axis, O' being the absolute origin. The line OX can be retained as the absolute axis by displacing the point of intersection of the dummy curve C (*IV*) in the proper direction along the X axis (line X' , O , X) by a distance equal to OO' . (In the case shown in Fig. 1 this point would be to the left of O at O'' .) In practice, however, such procedure usually results in the displacement of the reproduction curve D in the vertical direction by an inconvenient amount, and location of the new position of the absolute axis as indicated is usually more convenient. In some cases this method may result in the point O' falling outside the limits of the available coördinates, in which case its location is best indicated by a dimension line carrying a numerical indication of its position relative to the apparent axis OX .

Now a straight line drawn through O' and making an angle of 45° to the line of $O'M$ is the curve E , of absolute reproduction, this term

being used to denote an exact reproduction in the material reproduction of both the brightness and contrast of the object. For any point on the reproduction curve D the magnitude of the departure from an exact reproduction of brightness is given by the length of the perpendicular line limited by the two curves D and E and drawn through the point considered; while the relation of the slopes (first derivatives) of the curves at corresponding points (B_a and B_x , for instance) determines the magnitude of the departure from exact reproduction of the contrast in the object at the point (b) considered.

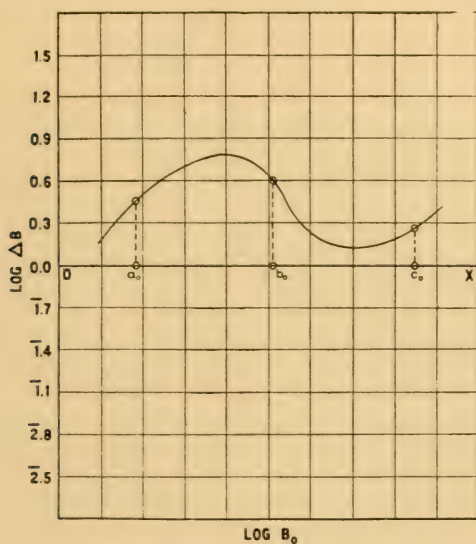


Fig. 2. Curve of brightness deviations.

The fact that the curve E is the curve for the exact reproduction of brightness follows from the construction, which is such that for any point on this curve $\log B_o$ is equal to $\log B_{mr}$, thus satisfying the necessary condition that $B_o = B_{mr}$. The fact that a given brightness interval of the object is represented by the same brightness interval on the curve E indicates that the contrast of the object has been exactly reproduced. A straight line at 45° to the axis is the necessary condition for exact contrast reproduction, while for exact reproduction of brightness this line must pass through a certain specified point on the $\log B_{mr}$ scale.

From the position of the curve E relative to D (the reproduction curve), it is possible to determine quantitatively the magnitude of the departure from the condition of exact brightness reproduction. The most convenient method of expressing the magnitude of this departure is by the use of the ratio of the brightness of the object to

the corresponding brightness of the reproduction, which ratio will be designated by the symbol ΔB .

$$\Delta B = \frac{B_o}{B_{mr}}, \text{ or}$$

$$\log \Delta B = \log B_o - \log B_{mr}$$

It can be shown that $\log \Delta B$ for any particular value of $\log D_o$ is equal to the intercept between the curves E and D on the perpendicular line through that value of $\log B_o$. In Fig. 2 the values of $\log \Delta B$ are plotted as a function of $\log B_o$, the resultant curve representing the departures from absolute reproduction of brightness.

Analytical Considerations

Let us now apply the method of the differential calculus to the functions plotted in Fig. 1. Such treatment is especially useful in a determination of the contrast relations existing between the various elements. If at any point the ratio of some small increment ΔY (in the direction of the Y coördinate) to the corresponding increment ΔX (in the direction of the X coördinate) be computed, the value obtained is a measure of the average slope of the curve over the distance (ΔX) considered. When these increments are reduced to the infinitesimal dy and dx the ratio gives the value of the slope at a point on the curve. Hence, if the slope or gradient be designated by the sym-

bol G , it is defined by the expression $G = \frac{dy}{dx}$. Applying this to the

curves of Fig. 1, the following expressions are obtained.

The density gradient of curve A , the characteristic of the negative materials (X), is given by

$$G_n = \frac{dD_n}{d \log E_x}$$

Since $d \log E_x = d \log B_o$ this becomes

$$G_n = \frac{dD_n}{d \log B_o}$$

likewise for B , the characteristic of the positive material (Y), the density gradient is,

$$G_p = \frac{D'_p}{d \log E_y}$$

While for the reproduction curve D

$$G_{nr} = \frac{d \log B_{mr}}{d \log B_o}$$

From the construction of the diagram (Fig. 1), it will be seen that

$$d \log E_y = -d D_n$$

and

$$d \log B_{mr} = -d D'_p = d \log R_p$$

$$\therefore G_n = - \frac{d \log E_y}{d \log B_o}$$

and

$$G_p = - \frac{d \log B_{mr}}{d \log E_y}$$

$$G_n \times G_p = - \frac{d \log E_y}{d \log B_o} \cdot - \frac{d \log B_{mr}}{d \log E_y} = \frac{d \log B_{mr}}{d \log B_o} = G_{mr}$$

$$\therefore G_n, G_p = G_{mr}$$

Now for exact reproduction of contrast, it is necessary that $G_{mr} = 1.0$. The condition fulfilling this requirement is that the product of the gradient (or slope) of the negative characteristic by the gradient of the positive characteristic shall be equal to unity. If G_n, G_p is greater than unity, a given brightness difference in the object ($d \log B_o$) is rendered in the positive by a brightness difference ($d \log B_{mr}$) greater than that existing in the object and hence the contrast is increased or the contrast scale is expanded. On the other hand, if G_n, G_p is less than unity it indicates that the brightness difference in the positive is less than the corresponding difference in the object ($d \log B_{mr} < d \log B_o$) and it follows that the contrast is decreased, that is, the contrast scale is compressed. Turning now to a consideration of the most convenient method of showing graphically the departure from exact reproduction of contrast, it is found that a curve showing the relation between B_o and the slope (G_{mr}) of the reproduction curve D fulfills all the requirements.

$$G_o \text{ (curve } E) = 1.0 \text{ by construction}$$

$$G_{mx} = \frac{d \log B_{mr}}{d \log B_o} \text{ (curve } D)$$

$$\frac{G_{mx}}{G_o} = \frac{d \log B_{mr}}{d \log B_o} \text{ (curve } D)$$

$$\therefore G_o = \frac{d \log B_o}{d \log B_o}$$

The value of the first derivative of curve D at any point is, therefore, numerically equal to the ratio of the gradient of curve D to that of E , and hence is a measure of the departure from exact contrast reproduction. In Fig. 3 is plotted the value of $\frac{d \log B_{mr}}{d \log B_o}$ (for curve

D) as a function of B_o . The $\log B_o$ scale is again a duplicate of that in Fig. 1, and the ordinates are gradient values. The condition that $G_{mr} = 1.0$ is that for exact contrast reproduction, and hence the line OX ($G_{mr} = 1.0$) is the curve of exact contrast reproduction. Points lying above this line ($G_{mr} > 1.0$) indicate an increased contrast in the positive while points below ($G_{mr} < 1.0$) correspond to a diminished contrast. In case a given difference of brightness ΔB_o in the object is

rendered by a greater brightness difference ΔB_{mr} in the reproduction, the contrast scale is said to be expanded while the opposite condition is expressed as a compression of the contrast scale. These conditions may be expressed mathematically, thus,

1. Increased contrast (expansion of contrast scale);
 $G_{mr} > 1.0$
2. Exact contrast reproduction (normal contrast);
 $G_{mr} = 1.0$
3. Diminished contrast (compression of contrast scale).
 $G_{mr} < 1.0$

In dealing with the straight line portion the gradient values are constant, and hence are direct measures of the contrast reproduction in such regions.

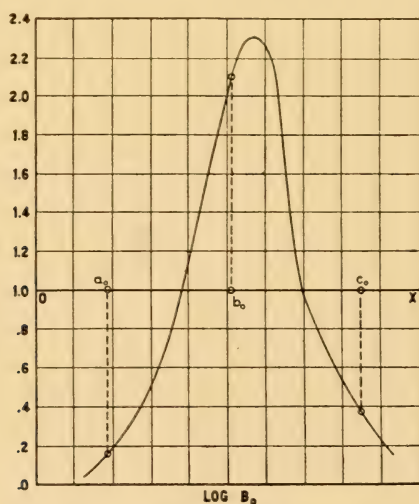


Fig. 3. Curve of contrast deviations.

Thus far, no assumption has been made relative to the shape of the curves A and B , the treatment having been of a general nature. In practice it is found that both of these curves may, within the limits of observation, be straight lines over a considerable portion of their lengths. The tangent of the angle which such straight portion makes with the $\log E$ axis is designated by the symbol γ , and is equal to the

gradient $\left(\frac{dD}{d \log E} \right)$ at any point on the straight line portion. The

gradient being constant throughout such straight portions, it is convenient when dealing with one tone reproduction by such portions alone to replace the values of gradient by those of gamma. The relation thus obtained is

$$\gamma_n \cdot \gamma_p = \gamma_{mr}$$

This it may be noted is the relation deduced by Porter and Slade, which is a special case of the more general relation between the gradi-

ent values. The special case is, of course, simpler to deal with and is applicable when the entire reproduction can be obtained by use of the straight line portions, which frequently occurs when the positive is made to be viewed by transmitted light (transparencies, *etc.*). In the case of a positive to be viewed by reflected light, it is usually necessary to utilize the entire scale of the positive material, including the curved portions as well as the straight line, and in such cases the special relation ($\gamma_p \gamma_n = 1.0$, for exact contrast reproduction) is practically useless, it being necessary to employ the more general form, $G_n G_p = 1.0$.

For that brightness range of the object which can be rendered by the use of deposits in the negative and positive situated on the straight line portion of the characteristic curves of both materials, the above relation may be used. Stating this relation in words, for the most general case, where the gradient is varied from point to point, the product of the gradient of the negative by the gradient of the positive is equal to the gradient of the reproduction curve. This applies only, of course, to the gradient values determined at the corresponding points on the three curves, corresponding points being defined as any three points related to each other as the point b_n , b_p , and b_r (Fig. 1). Or, for the straight line portions where gradient is constant and replaceable by gamma, the product of the gamma of the negative by that of the positive is equal to that of the reproduction curve. It may be of interest to note at this point that this is precisely the same relation as that derived by the author in collaboration with Mr. Wilsey when applying this general method to the problem of measuring the color coefficient of photographic deposits. And, since, for exact contrast reproduction, the slope (γ) of the reproduction curve must be unity, the necessary condition is expressed by

$$\gamma_n \gamma_p = 1.0$$

or

$$\gamma_n = \frac{1}{\gamma_p}$$

It should be borne in mind, however, that this relation holds only for the straight line portion of the curves, while the relation between the values of the differentials G_n , G_p , and G_{mr} is general and valid for any point regardless of the shape of the curves.

From a complete knowledge of the characteristics of the negative and positive materials, it is now possible to compute the quality of reproduction obtainable. It is also evident from the construction of Fig. 1 that if only one of these functions is known, that of the other can be obtained either graphically or by analytical methods provided an assumption as to the shape of the reproduction curve D be made.

In the original article several graphic examples are shown in which the shape of the negative and positive characteristics are determined as required to give correct reproduction under certain specified conditions. By the application of analytical methods many interesting relations between the characteristics of the negative and positive materials and the brightness contrast of the object are derived. For instance, it is

pointed out that if the negative and the printing paper be such that the "density scale" of the negative is equal to the "exposure scale" of the positive material all the density differences in the negative would be rendered as density differences in the print, and further that the maximum negative density will be rendered as the minimum useful density of the printing material, while the minimum negative density will result in the maximum useful density in the print. Such procedure, of course, results in diminished contrast in extreme shadows and highlights, due to the shape of the characteristic curve of the printing paper, even though (as is usually possible) all of the object brightnesses are rendered on the straight line portion of the negative curve. While in some special cases better results may be obtained by some other procedure it is undoubtedly true that in general the most favorable relation between negative and printing paper is that the density scale (DS_n) of the former should be as nearly as possible equal to the exposure scale (DS_y) of the latter.

The fulfillment of this condition, as was pointed out in a previous paper on this subject, makes the correct development time for a negative a function of the contrast in the object. Thus in order to utilize the available density scale of a printing paper, it is necessary to give greater development times to negatives of subjects in which the contrast is low than to those in which the contrast is high.

The applications of the methods outlined to practical problems are too numerous to mention in detail at this time. However, a specific example, Fig. 4, is shown. This illustrates the reproduction resulting from the use of negative and positive materials, the characteristic curves of which have been carefully determined by sensitometric measurements in this laboratory. The data, essential to this discussion, relative to the materials are as follows:

The negative material:

$$EL_x \text{ (Exposure latitude)} > 2.0 \text{ (in log } E)$$

$$\log i = \overline{2.5}$$

$$\gamma_{\infty} > 1.00$$

The positive material (a developing-out paper):

E_s	(Standard exposure)	= 100,000 (m.c.s.)
γ_{∞}		= 1.34
EL_y	(Exposure latitude)	= 0.77 (in log E)
ES_y	(Exposure scale)	= 1.50 (in log E)
DL_y	(Density latitude)	= 1.06
DS_y	(Density scale)	= 1.43
$D_{\max}$	(Maximum density)	= 1.45
R_b	(Reflecting power of fog strip)	= 0.80

Let it be assumed that the highest object brightness is 1000 (apparent meter candles), and that this brightness is to be rendered in the positive by a just perceptible density [$D = 0.01$ (approximately), $R_b' = 0.02$].

In order to illustrate the effect of contrast to which the negative is developed on the quality of the resulting reproduction, three different negative characteristics are plotted, differing only in the value of gamma. The resultant reproduction in the three cases is given by the curves D_1 , D_2 , and D_3 . Applying the equations, it is shown that T_* (exposure time in making the negative) is 0.0126 second, that the exposure times in making the three prints are 71, 135, and 250 sec-

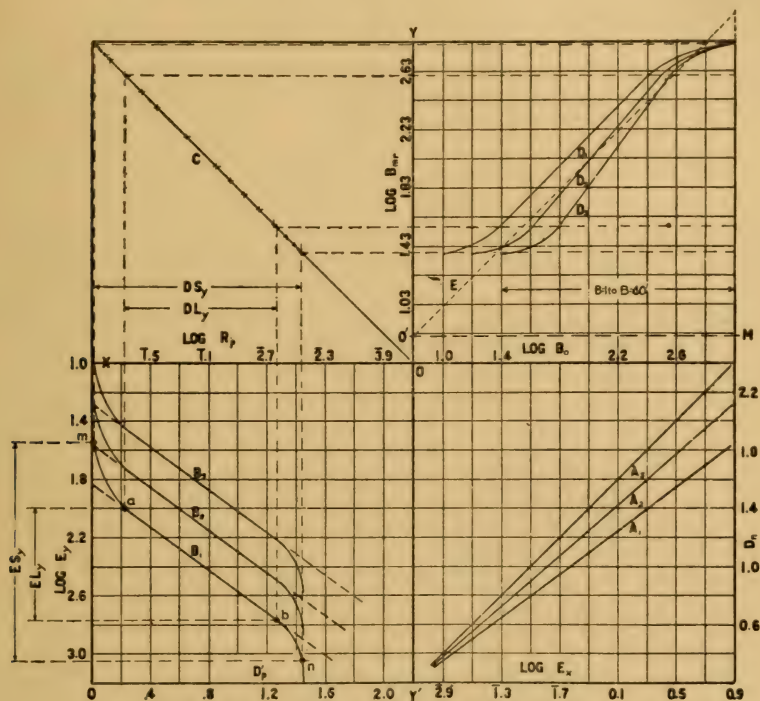


Fig. 4. Objective reproduction obtainable with specified materials and conditions

onds for the three cases. The results are analyzed by plotting the departure curves, and it is shown that curve D_2 gives the least average departure from exact reproduction for the subject having a brightness contrast of from 1 to 40.

The Subjective Phase

Turning now to a consideration of the subjective phase, it will be well to discuss the significance of the curves shown in Fig. 5. These contain the data relative to the visual sensitivities necessary for the evaluation of the subjective relative contrast function. Curve A gives the relation of the sensation to the stimulating brightness. Equal increments on the Y axis correspond to equal increments in the sensation, and the brightness intervals which give rise to these sensation

steps can be determined from this curve. The shape of the function could be established by direct experiments, but since such a process is extremely laborious, it is customary to arrive at the same end by other means. The curve *B*, the contrast sensibility, is the first derivative of the sensation curve, hence, if the sensibility be measured and the curve *B* plotted, the sensation curve may be obtained by integration. The sensibility at a given adaptation level is determined by measuring the least difference in brightness perceptible under the specified conditions. The least perceptible difference, ΔB , expressed as a fraction of the brightness at which it is determined, is a direct measure of the sensibility of the eye to contrast or brightness difference. The ordinate of curve *B* at any point is therefore equal to the slope of the curve *A* at

the same value of *B*. Thus, if *S* be the sensation, $\frac{dS}{d \log B} = \frac{B}{\Delta B}$.

The values of the ordinates of the sensation curve are in terms of sensation units, and the construction of such a sensation scale is based on the assumption that a just perceptible difference at any point on the sensation scale is equal to a just perceptible difference at any other point. The basic unit upon which this scale is established is therefore the least perceptible brightness difference.

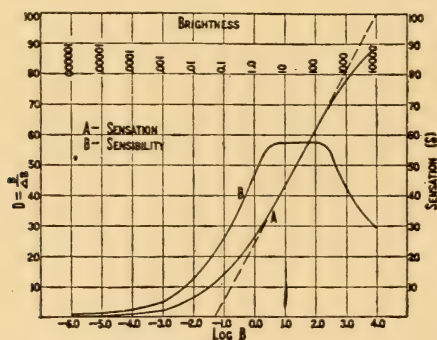


Fig. 5. Contrast sensitivity curves of the eye.

The range of brightness over which the eye operates is enormous, from $B = 0.000001$ to $B = 10,000$ millilamberts, a range of 1 to 10,000,000,000, while for the photographic plate the corresponding range is but 1 to 2000 (approximately). This extreme range in case of the eye is due largely to the fact that the retina changes in sensibility with the intensity of the incident radiation. This property of variable sensibility has been likened to that of an ammeter equipped with a shunt whose resistance decreases as the current increases. The diameter of the pupil is but a very small factor in the sensibility change since it varies in area over a range of but 1 to 64. It should be pointed out that the curves in Fig. 5 are similar in shape to those given by Renwick, but that the absolute values of log brightness are

very different. This is undoubtedly due to the uncertainty in the value of the unit used by König, from whose data the curves in question were plotted. Blanchard has discussed the question and has computed the probable value of König's unit as being 0.004 ml. (approximately). The millilambert is the c.g.s. unit of brightness, and is equivalent to a brightness of ten meter-candles or 0.93 foot-candles. The region of maximum sensibility is therefore from 3 to 250 foot-candles (approximately), instead of from 20,000 to 400,000 as indicated by the curves published by Renwick. Since the function of use in relating subjective reproduction to the objective contrast is obtained by using the ratio of the gradients at two points on the sensation curve, the units in which the curve is plotted are not of importance. However, in order to determine the sensibility for a given adaptation level, it is important that the correct abscissa value be used.

Now, if we consider a specified brightness difference in the object viewed with the eye adapted to some brightness level A_0 it is possible from curve A (Fig. 5) to find the corresponding sensation difference; and if the brightness difference between the corresponding areas of the material reproduction be known, together with the adaptation level (A_{mr}) of the observer viewing this material reproduction, it is possible to determine also the magnitude of the resulting subjective contrast. A comparison of the magnitudes of these two contrast values, namely: (a) the subjective contrast resulting from observation of the object at a given adaptation level, which subjective evaluation it is convenient to refer to as the subjective object; and (b) the subjective contrast due to the observation of the material reproduction at a specified adaptation level, which subjective evaluation will be termed the subjective reproduction, determines the exactness with which the subjective sensation resulting from the observation of the object is reproduced by observation of the material reproduction (the illuminated positive) under the conditions specified. It is also possible by similar methods to determine the magnitude of the contrast necessary, at any point in the tonal scale of the material reproduction, for the exact reproduction of the subjective contrast of the object, assuming, of course, that the values of A_0 and A_{mr} are known,

A_0 = Adaptation level while observing object

A_{mr} = Adaptation level while observing material reproduction.

For instance, in Fig. 6 consider an increment of brightness, $\Delta \log B_1 = \log B_1 - \log B_1'$, for which the corresponding increment in the sensation is $\Delta S_1 = (S_1 - S_1')$. At any other point take a second increment in sensation $\Delta S_2 = (S_2 - S_2')$ such that $\Delta S_1 = \Delta S_2$. Let the increment in $\log B$, corresponding to ΔS_2 be represented by $\Delta \log B_2 = (\log B_2 - \log B_2')$. Assume that the increment $\Delta \log B_2$ applies to some point in the object, and that the value of $\log B$ fixes the adaptation level of the observer looking at that object, while for the material reproduction the adaptation is conditioned by the value of B_1 .

$$\begin{aligned} A_0 &= B_2 \\ A_{mr} &= B_1 \end{aligned}$$

Now the average slope of the curve (Fig. 6) over the range $\Delta \log B_2$ is given by

$$\text{Slope (2)} = \frac{\Delta S_2}{\Delta \log B_2}$$

And the average slope over the interval $\Delta \log B_1$ is likewise

$$\text{Slope (1)} = \frac{\Delta S_1}{\Delta \log B_1}$$

Since $\Delta S_1 = \Delta S_2$ it follows that

$$\frac{\text{Slope (2)}}{\text{Slope (1)}} = \frac{\Delta \log B_1}{\Delta \log B_2}$$

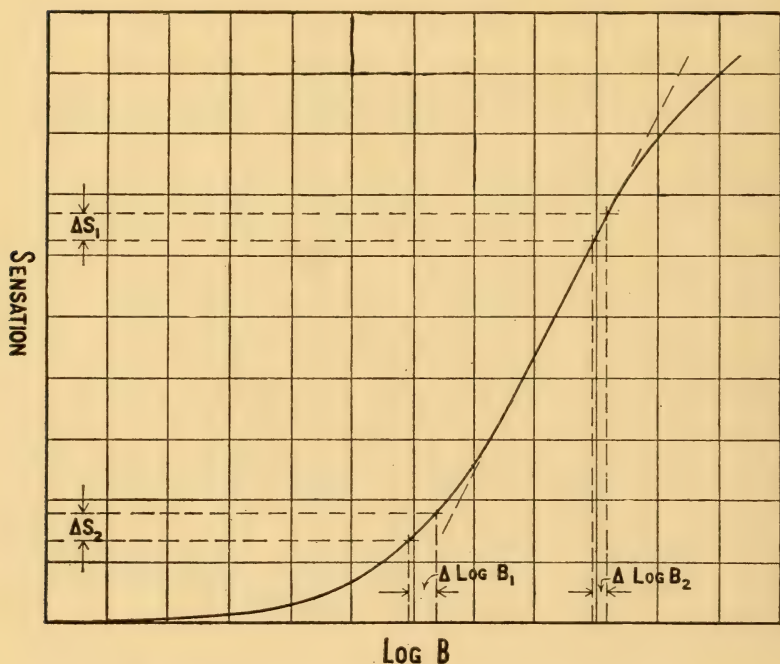


Fig. 6. The relation between sensation and stimulus.

But the average slope of the sensation curve over any given interval is given by the average value of the ordinate D of the contrast sensibility curve (curve B , Fig. 5) over the same interval. Hence, we may express the values of the slope by the corresponding values of D , and equation becomes

$$\frac{\text{Average } D_2}{\text{Average } D_1} = \frac{\Delta \log B_1}{\Delta \log B_2}$$

or

$$\Delta \log B_2 = \Delta \log B_1 \cdot \frac{\text{Average } D_1}{\text{Average } D_2}$$

It is evident, therefore, if $\Delta \log B_2$ be the objective brightness difference at some point in the object, that the equation will give the value of the $\Delta \log B_1$ the objective brightness difference necessary in the photographic reproduction for the exact reproduction of subjective contrast. In the case illustrated, the interval $\Delta \log B_2$ is less than the interval $\Delta \log B_1$, thus indicating that a greater objective contrast in the reproduction will be required to reproduce the subjective contrast due to the smaller objective contrast in the object.

It is well known that other factors than the brightness of the area upon which the attention is fixed (foveal image) influence to some extent the adaptation level of the eye at any instant. Such factors include the brightness of the surrounding objects (*i. e.*, the peripheral images), and the length of time during which the attention has been fixed on the area considered. In practice, however, the picture being observed occupies a very considerable portion of the field of vision, and, further, in the great majority of such pictures the actual range of brightness is relatively limited. This is especially true of surfaces viewed by reflected light. Further, under the majority of conditions, the field of vision not filled by the reproduction being considered does not contain any area contrasting extremely with the brightness of the reproduction. It seems reasonable, therefore, to assume that the adaptation level will be fixed in practice by the brightness of the reproduction itself, and likewise that the level when viewing the object will be conditioned by the object considered.

The question then arises as to what particular brightness in object and reproduction will determine the adaptation level in each case. Considering the reproduction as a reflecting surface, the average range of brightness may be taken as 1 to 40 (1.6 in $\log B_{mr}$), which, even at the steepest part of the sensibility curve (Fig. 5) does not correspond to an excessive change in value of D . The change in adaptation as attention travels from highlight to shadow probably is not so great as that indicated by the brightness range, being limited to some extent by the stabilizing effect of the peripheral image as well as to the time lag of adaptation behind the changing foveal stimulus. It seems logical, therefore, to assume that A_0 and A_{mr} are conditioned by the average brightness of object and material reproduction, and this assumption will undoubtedly hold for a large percentage of the normal cases, although it may be necessary, under extreme conditions, to take into account the change in adaptation (and consequently in the value of D) which occurs as attention shifts from an area of one brightness to that of another.

As a simplifying condition, let us, therefore, assume that the adaptation level is conditioned by a brightness of the object and reproduction, respectively, half-way between (on the $\log B$ scale) the highest and lowest brightness considered.

Let the values of the various factors be designated by:

For the object:

A_0 = Adaptation level for average B_0
 D_0 = Sensibility

For the reproduction:

$$\begin{aligned} A_{mr} &= \text{Adaptation level for average } B_{mr} \\ D_{mr} &= \text{Sensibility} \end{aligned}$$

Now in the equation previously given,

$$\frac{\text{Average } D_2}{\text{Average } D_1} = \frac{\Delta \log B_1}{\Delta \log B_2}$$

let the numerical subscripts be replaced by the subscript letters indicating the application of the terms to particular values, thus,

$$\frac{\text{Average } D_o}{\text{Average } D_{mr}} = \frac{\Delta \log B_{mr}}{\Delta \log B_o}$$

By allowing these finite increments to approach zero as a limit, we may replace the average values of D by values of the slope of the contrast sensibility curve at a point and obtain the expression

$$\frac{D_o}{D_{mr}} = \frac{d \log B_{mr}}{d \log B_o}$$

Since an assumption of equality of subjective contrast (sensation increment) has been made, this equation is a statement of the conditions necessary for the exact reproduction of the subjective contrast.

Now the value of $\frac{D_o}{D_{mr}}$ gives the slope of a curve which if plotted

in quadrant I, Fig. 1, would be the line of exact subjective reproduction of objective contrast. In the graphic solution, however, it is more convenient in plotting the reproduction curve D , and also in the later interpretation of the results, to retain the line E (of which the gradient is unity) as the line of exact contrast reproduction, and to alter the position of the points on the scale on the line O so that the reproduction curve plotted therefrom will be the curve of actual subjective reproduction, this alteration of position being an expansion or compression of the points on the scale in the case of constant values for the adaptation levels (A_o and A_{mr}), or a distortion of their distribution in case such values are variable. It is quite possible to obtain the final evaluation of the exactness of reproduction as a comparison between the contrast values of the subjective object and the subjective reproduction (see Table I, Items I and X), but in view of the fact that the starting point in any tone reproduction problem must be the objective brightness values of the object, it seems more logical to make these values the primary base of the computation and to express finally the departures from exact reproduction in terms of these physically measured values of object brightness. This necessitates the evaluation of the subjective contrast of the reproduction in terms of the subjective contrast of the object, and a final expression of this complex relation as a function of the object brightness B_o . The final comparison must therefore be made between the actual measured (objective) contrast values of the object and the corresponding contrast values of the subjective reproduction evaluated in terms of the subjective object.

The scale on which the points representing the various areas of the reproduction, as evaluated in terms of this relative subjective contrast function, must occupy the line OY in order that the curve representing the final reproduction may be graphically constructed with values of B_0 as abscissas. The required scale constructed on line OY will be termed the $\log B_*$ scale, and the relative subjective contrast function which is used to determine the distribution of the points on the $\log B_*$ scale will be referred to as the Z function, and its gradient will be designated by G_* .

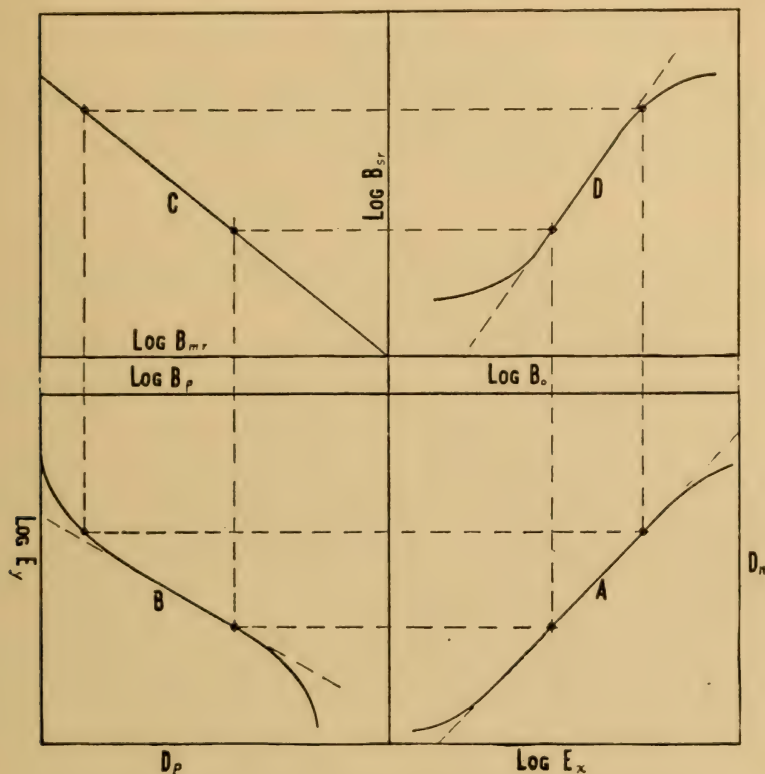


Fig. 7. Special case of the complete solution including subjective phase.

Now in order that the line E (in quadrant I), having a slope of unity, shall be the line of exact subjective contrast reproduction, it is necessary that its slope or gradient be given by the expression

$$G_* = \frac{\Delta \log B_*}{\Delta \log B_0}, \text{ where } \Delta \log B_0 \text{ is some increment on the } \log B_0 \text{ scale for}$$

which the corresponding interval in the subjective reproduction is $\Delta \log B_*$. Let the scale of $\log B_{mr}$ on line OY (Fig. 1) be replaced by

a scale of $\log B_z$ (Fig. 7). This can be accomplished by replacing the dummy curve C (Fig. 1) by the new function which gives the relation between the material (objective) reproduction and the subjective reproduction. This subjective reproduction is itself a complex function containing the relation between the subjective evaluation on the object and subjective evaluation of the material reproduction. These evaluations are conditioned by the sensibility of the eye to brightness differences (contrast) at the time of observing the object and when viewing the reproduction. This relation, the relative subjective contrast function, can be constructed graphically, but the consideration of this will be omitted. It is sufficient for the present purpose to state that the gradient of this curve, which must be substituted for the dummy curve thus far used, is equal to the reciprocal of the ratio of the values of D_o to D_{mr} . Let G_z indicate the gradient of the relative subjective contrast function which from this point on will be used instead of the dummy curve, having an arbitrary gradient equal to unity. Then

$$G_z = \frac{D_{mr}}{D_o}$$

This procedure also makes it possible to establish on the line OY the scale $\log B_z$ (Fig. 7), for which the points located by the usual construction methods will represent the relative subjective brightnesses corresponding to the various areas of the object considered.

Now if

$$\begin{aligned} D_o &= D_{mr} \\ G_z &= 1.0 = G_d \end{aligned}$$

This is the gradient thus far used in the construction of the curve C . It is evident, therefore, if average B_o and average B_{mr} are such that they fall between the limits (Fig. 5), $\log B = 0.5$ ($B = 3.2$ ml.) and $\log B = 2.2$ ($B = 166$ ml.), that the subjective reproduction of contrast will be identical with the material reproduction curves already discussed.

If, however, the brightness B_o of the object and the consequent adaptation level A_o of the observer viewing that object is relatively high, while the brightness of the material reproduction, B_{mr} (the illuminated positive), and the corresponding adaptation level A_{mr} is low, the subjective reproduction will be different from the objective reproduction. In this case the contrast sensibility D_o is greater than D_{mr} and hence the gradient, G_z , of the relative subjective contrast curve is less than unity.

$$G_z = \frac{D_{mr}}{D_o}$$

The reproduction curve D constructed in the usual way will also have a decreased gradient. This indicates that under such conditions a loss of contrast occurs due to the subjective factors, and in order to obtain exact subjective reproduction it will be necessary to enhance the objective contrast in material reproduction, in order to compensate for the loss due to the subjective effect. It is evident from these consider-

ations that a picture of a brilliantly lighted scene, which is to be viewed under relatively low illuminations, such as exist in interiors at night, should be somewhat more contrasty than the scene itself. That is, best subjective reproduction will be obtained by a positive in which the actual objective contrast is somewhat enhanced. This condition may be stated symbolically thus:

$$\begin{aligned} \text{If } D_o \text{ is greater than } D_{mr} \\ G_s \text{ is less than } 1.0 \end{aligned}$$

When G_s is less than unity there will be a loss of contrast due to the subjective factors.

On the other hand, if

$$\begin{aligned} D_o \text{ is less than } D_{mr} \\ G_s \text{ is greater than } 1.0 \end{aligned}$$

and there will be an enhancement of contrast due to the subjective factors. When G_s is greater than unity the slope of the relative subjective contrast function (curve C is quadrant IV) is greater than unity, and the gradient of the resulting reproduction curve D (quadrant I) is increased accordingly.

Now from a consideration of Fig. 7 it will be seen that for the straight line portions of the curves, if such exist,

$$\gamma_r \cdot \gamma_p \cdot \gamma_s = \gamma_r$$

Therefore if any three of these four functions involved be known or are assumed, the fourth may be determined. The line E is, as before, the curve of exact reproduction of contrast, and the curve D is the reproduction obtained under the specified conditions. Deviations may be determined as in case of the solution for the objective phase, and the results will indicate the departure from the exact reproduction of subjective contrast. It should be noted that this construction gives direct comparison between the objective values of brightness and the relative subjective equivalent in the reproduction. That is, the comparison is not between the subjective impression of the object and the subjective impression due to the reproduction, although this comparison can easily be made if such seems desirable. The procedure adopted is such that all of the subjective factors are introduced by use of the curve C , the relative subjective contrast function. Such procedure is in effect the evaluation of the subjective reproduction in terms of the subjective contrast in the object itself.

Now in case it is considered necessary, by reason of the existing conditions, to take into account the change of adaptation with shift of attention from highlight to shadow, this can be accomplished by computing for each pair of object and reproduction brightnesses the value

of the ratio $\frac{D_{mr}}{D_o}$, and from the values thus obtained plotting a curve

which is then used as the relative subjective contrast function. The curve C may not, under such circumstances, be a straight line, but

will vary in slope as indicated by the computed values of $\frac{D_{mr}}{D_o}$. As a

typical example of such a case computed from actual values of a practical case, curve *C* in Fig. 8 is given. This is for an object in which the brightness range is from 15 ml. to 1000 ml., while the intensity of the illumination on the positive during observation is such that the brightness range is from 0.35 ml. to 10 ml.

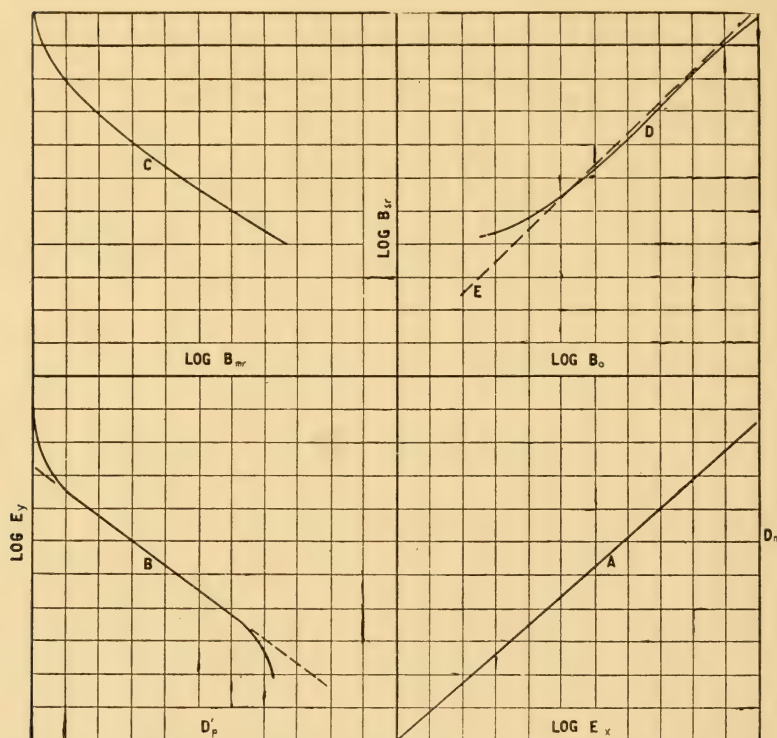


Fig. 8. A general case of the complete solution including the subjective phase.

Fig. 8, therefore, represents the complete general graphic solution giving the reproduction curve *D*, which is a graphic representation of the reproduction of the subjective impression obtainable under any set of specified conditions, the line *E* being the curve of exact reproduction of subjective contrast. It should be noted that with the particular values assumed in this case, the reproduction curve *D* is somewhat straighter in the highlight region than when a straight line was used as the relative subjective contrast function. It is probable in practice that the change in adaptation level is not so great as is indicated by the assumptions made in this case, and that the improvement in contrast reproduction is not so great as indicated by the curve shown.

Many interesting relations between the various factors may be derived and applied to practical problems, but the discussion of such details will not be taken up at this time. One point deserving mention, however, is relative to the values of adaptation of the eye, upon which depend the sensibility values from which the slope of the subjective relative-contrast function is computed. Few data are available at present as to adaptation levels when the visual field is filled by areas of different brightnesses, such as exist under practical conditions. Experimental work is in progress in this laboratory, from the results of which it is hoped more reliable evaluations of A_0 and A_{mr} may be obtained for certain specified practical conditions. When these data are available it will be possible by the application of the general principles outlined in this paper to arrive at more certain conclusions relative to the exactness of reproduction in any particular case.





Trees

Frank Powolny



Chains

Frank Tanner



The Clay Dancer

Frank Tanner



Along the Shore

Karl Struss, A.S.C.



On the Pier

Karl Struss, A.S.C.



Cactus

Hatto Tappenbeck, A.S.C.



Mission Garden

Frank Powolny



The Vegetable Girl

Elwood Bredell



On the Set

Elwood Bredell



Portrait Study

Karl Struss, A.S.C.



Portrait Study

Karl Struss, A.S.C.



Water Fall

Stacy Woodard



The Storm God

Elmer G. Dyer, A.S.C.



On the Trail

Elwood Bredell



Shadows

Elmer G. Dyer, A.S.C.



Microphone

Elwood Bredell



The "Chuck Wagon"

Elmer G. Dyer, A.S.C.



Sunset on the Java Sea

Lewis W. Physioc



Vernal Falls

Stacy Woodard



A Vase

Paul Allen, A.S.C.



The Model Rests

Paul Allen, A.S.C.



Baby Stare

Gilbert Warrenton, A.S.C.



Fishing Boats

Lewis W. Physioc



After the Haul

Maurice Kains



Branches

Gaston Longet



The Junk

Lewis W. Physioc



The Swamp

Jackson J. Rose, A.S.C.



Dawn at Fish Harbor

Maurice Kains



Peaceful Valley

Oliver Sigurdson



Prowlers

Gaston Longet



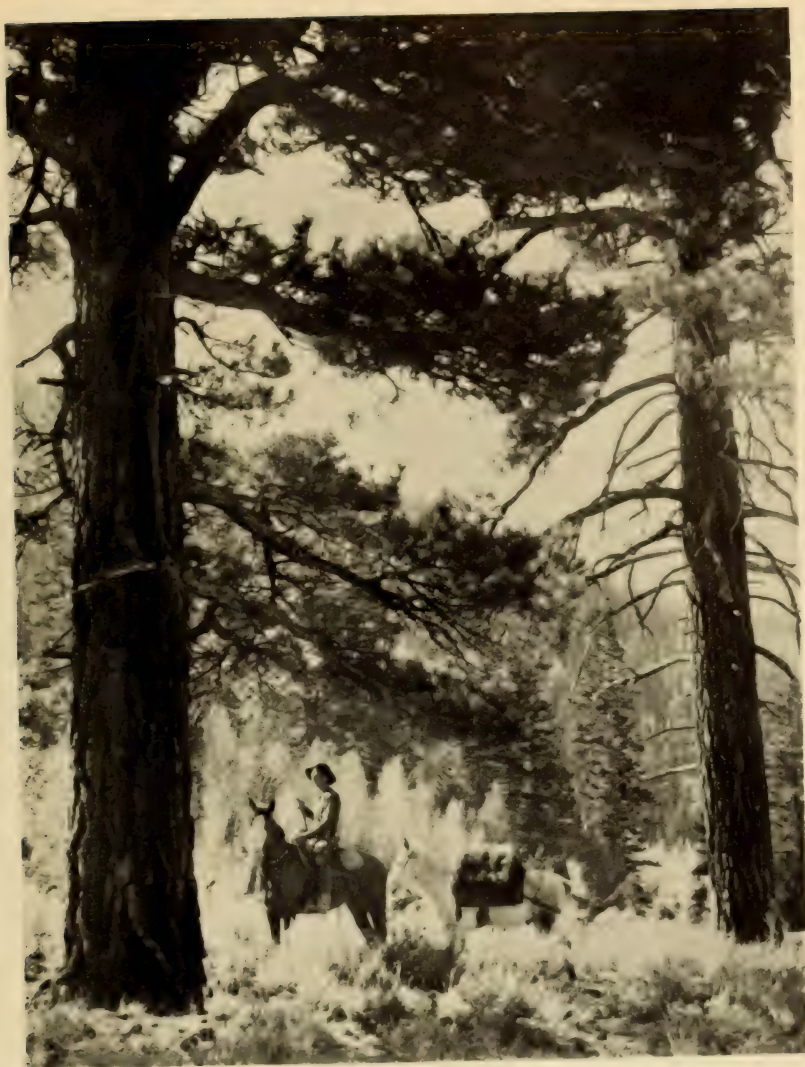
Character Study

Kenneth MacKenna



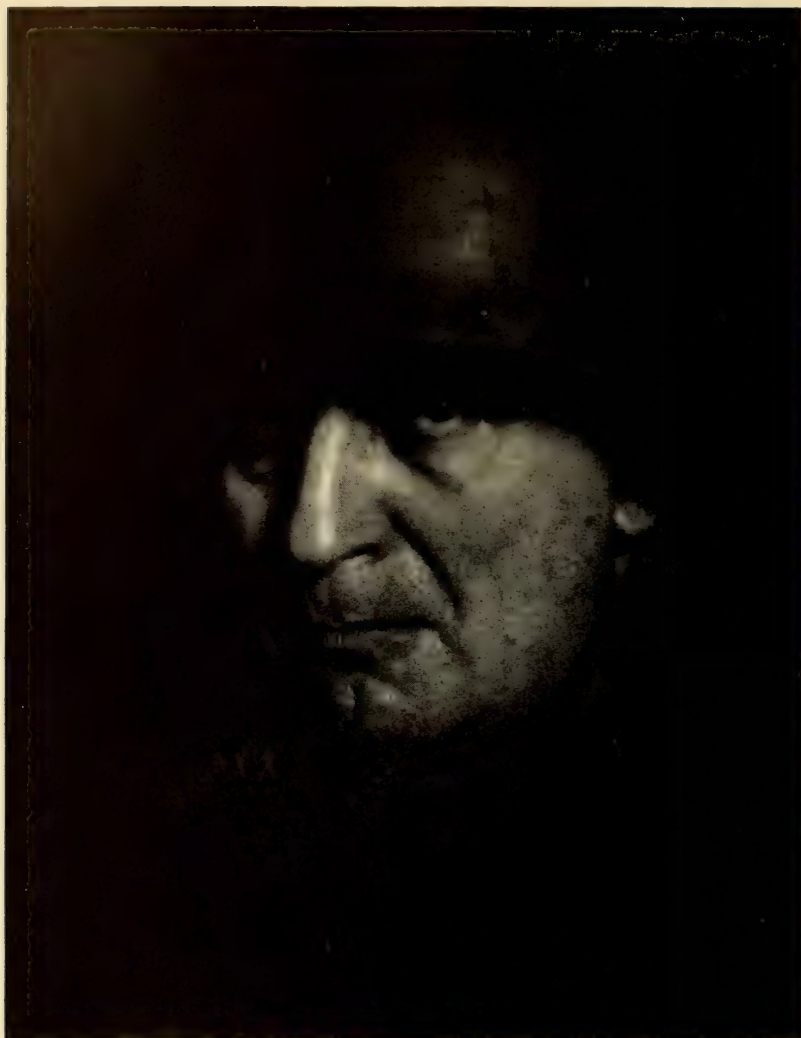
Sunset

Lewis W. Physioc



Big Timber

Gaston Longet



Portrait Study

Lawrence Grant



Portrait Study

Lawrence Grant



St. Ivan Bautista

Lawrence Grant



Elysian Vista

Ira B. Hoke



Pont Aven

Lawrence Grant



St. Jean Pied de Port

Lawrence Grant



Alone

Ned Van Buren, A.S.C.



Composition

Karl Struss, A.S.C.



Pictorial Study

Ned Van Buren, A.S.C.



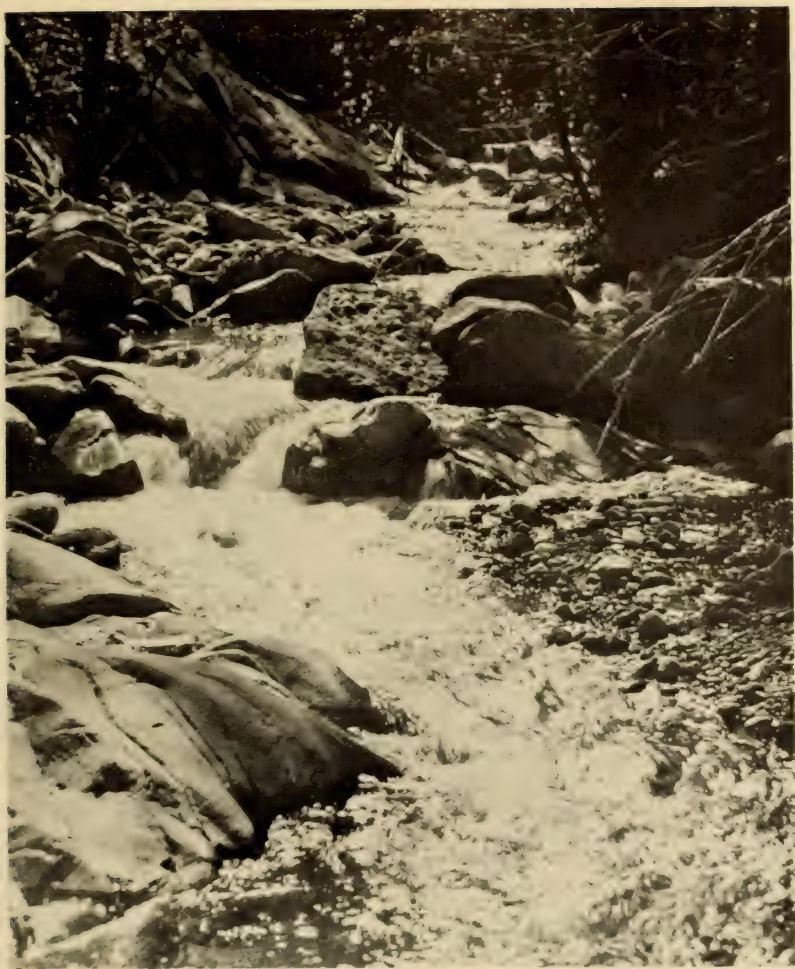
Desert Study

Ned Van Buren, A.S.C.



Meadow

Ned Van Buren, A.S.C.



Tumbling Waters

Elmer G. Dyer, A.S.C.



Frisky

Ira B. Hoke



Strength

Jackson J. Rose, A.S.C.



Desert Sentinels

Ned Van Buren, A.S.C.



Tramps

Ira B. Hoke



Margaret Livingston

Russell Ball



Noel Francis

Russell Ball



Despair

Russell Ball



Jean Harlow

Russell Ball



Guns (Ralph Forbes)

Russell Ball



Ruth Chatterton

Russell Ball



Jack Holt

Russell Ball



Desert Study

Ned Van Buren, A.S.C.



Ships That Pass In The Night

Fred R. Archer



Life

Frank Tanner



Singapore Harbor

Lewis W. Physioc



April

W. E. Hastings



In The Harbor

Karl Struss, A. S. C.



Sails

Fred R. Archer



"Up"

Elmer G. Dyer, A.S.C.

THE RELATIVE MASSES OF PHOTO-SILVER

*And Sensitivity Specks in the Photographic Latent Image**

S. E. Sheppard

RECENT investigations have made it possible to consider the problem of the formation of the latent image in a more definitely quantitative manner. It appears possible that this will lead to a somewhat changed conception of its nature.

In 1921 M. Volmer (1) made some calculations, on the assumption of an Einstein equivalence of one "altered AgBr molecule" to one quantum of absorbed light, of the ratio of altered to unaltered molecules. Taking Leimbach's data (2) for the light energy necessary for a density of 1.0 he obtained a ratio of 1 altered to 2×10^7 unaltered molecules in a grain of 10^{-4} cm. radius. If the decomposition was supposed limited to the surface of one hemisphere, the ratio could grow to 1 to 2×10^3 . Volmer draws some conclusions from this as to the insufficiency of the photo-product to act as nuclei for the Ostwald super-saturation theory of development. It was pointed out by the writer (3), however, that Volmer had not taken into account the "Reifungskeime" or "sensitivity specks."

In 1922, S. E. Sheppard and E. P. Wightman (4) recalculated the mass of "altered molecules" as silver atoms, on the assumption of 1 atom per quantum absorbed, and using Leimbach's data for the "Schwellenwerth," or threshold exposure. For a grain of $1\mu^2$ surface (10^{-4} cm. $\times$ 10^{-4} cm.) and 0.1μ thick, they found only 24 Ag atoms per grain; with the latter containing 2.06×10^9 molecules AgBr, this gives†

Decomposed	Undecomposed Molecules
1	8.6×10^7

This is assuming total absorption of the light incident on the grain surface, and quantum equivalence.

An even lower value is obtained if Leimbach's threshold energy for a still faster plate is used (5)

$$\text{viz. : } \frac{1.38}{10.5} \times 24 = 3 \text{ per grain.}$$

It is to be remarked that there is nothing in the evidence to show that grains of this size (ca. 1μ diameter) actually were made developable by the threshold exposure. The investigations of Jones, Huse and Hall (6) show that the reciprocity failure decreases with grain size, in so far as larger grains are more sensitive. Very high speed emulsions usually contain some grains up to 10 to $12\mu^2$ or even higher (7). One obtains the same ratio of altered to unaltered molecules, but the number of atoms of Ag (or "altered molecules") per grain, assuming same thickness, might be 10 to 12 times as great.

* Communication No. 459 from the Kodak Research Laboratories.

† Typographic error in original gives $1:86 \times 10^8$.

For the fastest plate examined this still leaves the number of silver atoms per grain (of $10\mu^2$) only about 30, and with no necessary condition that they be aggregated to a group of this order of magnitude.

In a recent paper by Eggert and Arens (8) an approximate calculation is given for the concentration of photo-silver in an Agfa Special Rapid plate for an exposure giving a density 1.0. Thus at $\lambda=450\text{ m}\mu$, the energy incident was 10^{-1} lux/cm^2 , equivalent to $2 \times 10^{11}\text{ quanta/cm}^2$. Assuming $10^{-3}\text{ gm. AgBr per cm}^2$ quantum equivalence and complete absorption, this gives $10^{-11}\text{ gm. photo-silver/cm}^2$.

$$\text{of } \frac{10^{-11}}{108 \times 1.66 \times 10^{-24}} \text{ atoms Ag/cm}^2$$

which is equivalent to 2,000 atoms Ag per $1\mu^2$. With lower absorption, and incomplete quantum equivalence, this could reduce to 500 atoms Ag per grain of $1\mu^2$. In an earlier discussion of the number of quanta of blue light required to make a developable, Eggert and Noddack (9) concluded from statistical determinations of Meidinger (10) that "under certain conditions one silver atom (corresponding to one quantum) could make a grain developable; on the other hand, even with 1000 silver atoms per grain, not all grains are developable." Eggert and Noddack interpreted this as follows: "If one reflects that even *unexposed* grains may happen to be developable (fog grains)—therefore evidently contain a nucleus—one is led to the conclusion that the *single* silver atom afforded by light serves to complete a nearly effective silver nucleus." According to this, developability of a grain is conditioned by the presence of a nucleus of "critical" size. This nucleus size, which is compounded of "ripening silver" and "photo-silver," is reached the more readily the greater the number of quanta incident per grain. For α — and X-rays the critical nucleus size is reached in any case, independent of the amount of "ripening silver."

It is to be noted that part of Meidinger's statistical data admitted the interpretation that *less* than one quantum could make a grain developable. Rejection of this, in favour of one quantum as the lower limit, evidently throws some doubt on the validity of assuming that even *one* quantum, one silver atom, could in any case make a grain developable. But it will be seen that these lower limit values are of the same order of magnitude as the photo-silver values at the threshold calculated by Sheppard and Wightman. It may be added here that experiments by Helmick (11) indicated some 400 to 500 quanta of light at $365\text{ m}\mu$ as necessary to make a grain of unspecified size developable, while energy measurements of Jones and Schoen (12) at a level giving a density of 1.00 on Eastman Graflex plates indicated 400 quanta for a grain of $1\mu^2$. For threshold values of exposure, this might be 1/10 to 1/100, which again brings the atoms per grain very low.

The above interpretation of grain sensitivity data given by Eggert and Noddack is in full accord with the conclusion reached by Sheppard, Trivelli and Loveland (13) with regard to the function of

‡ Values found in this Laboratory give 1 to $1.6 \times 10^{-3}\text{ gm.}$

"sensitivity specks." They concluded that the apparent sensitizing action of a speck is "confined to increasing its size by accretion of photochemically reduced silver atoms to form a nucleus *large enough* to induce developability." It was suggested, following Svedberg (14), that the minimum size might be of the order of the minimum gold nuclei found effective by Zsigmondy—comprising about 300 atoms. All the figures for the amount of photo-silver per grain thus far have been purely estimates based on assumed quantum equivalence, *etc.*, or extrapolations back from the visible exposure region, where concentrations amenable to chemical analysis were available (15). In a recent very important paper by Hilsch and Pohl (16) estimation is replaced by measurement of the number of "absorbing centres" produced in a single silver halide crystal by a known amount of absorbed light energy.

The number of "centres" found gave a quantum equivalence of about 0.3 to 0.4. That is, assuming each centre to be a silver atom, the number found was considerably less than full equivalence. In the case of the alkali halides, close approach to equivalence (0.90) was found. It is notable, however, that the absorption curves of the silver "centres," or photo-products, were considerably broader, indicating greater complexity in the silver centres than in the case of the alkali metals. It is very possible that the silver absorption curve corresponds to a certain proportion of poly-disperse particles (binary, tertiary, *etc.*) while the alkali metals gave practically mono-disperse monatomic systems.

Calculation of the concentration or mass of latent image by Hilsch and Pohl gives 5×10^{-7} grams Ag per 1 gram AgBr for a "well developable" image on a fast plate at 1/50 second. They allow that such an image could still be found at 1/500 second, hence giving 5×10^{-7} to 5×10^{-8} gm. silver per 1 gram AgBr. From their actual absorption measurements on single silver bromide crystals, they obtain a value 10^{-7} gm. Ag per 1 gm. AgBr, *i. e.*, the same order of magnitude, indicating that they were measuring the absorption of the "latent image." They point out that the "visibility" of the image is simply a question of the thickness of silver halide.

Collecting these results we have the following tabulation:

Datum.	Concentrations of Latent Image.	
	Grams Ag per 1 gram AgBr.	Ag atoms per grain $1 \mu \times 0.1 \mu$
Sheppard and Wightman:		
Leimbach's Medium Speed	3.6×10^{-9}	24
" Extra Rapid	2×10^{-10}	3
Eggert and Arens. Density = 1.0:		
Agfa Special	10^{-8}	860
Meidinger		1 to 1000
Hilsch and Pohl:		
(a) "Well developable"	0.5×10^{-7}	4300
(b) Same, extra rapid	$.5 \times 10^{-8}$	430
Jones and Schoen:		
Density = 1.0	(0.5×10^{-8})	400
Threshold	$(.5 \times 10^{-9})$	40

These values for the concentration of photo-silver, especially the lower limits, are particularly interesting when compared with some

recent determinations of "sensitivity speck" materials in silver bromide emulsions. Weigert and Lühr (17) made determinations of "Ursilber" (ripening silver) in certain emulsions they prepared, which gave quantities of silver of the order of 10^{-6} grams Ag per 1 gram AgBr. Eggert and Arens regard these as improbably large, partly by contrast with the above detailed "photo-silver" estimations, partly by contrast with effective amounts of other sensitizing and desensitizing substances. Thus they found that the addition to a certain emulsion of about 10^{-6} grams allylthiourea per 1 gram AgBr increased speed and density more than ten times. Again, an addition of about 2×10^{-6} grams *methylene blue* per 1 gram AgBr produced a *desensitization* to 1/10. In terms of molecules, this is again a quantity of about 1/5 the number of allylthiourea molecules.

On the other hand, Sheppard (18), in a series of experiments on the effect of concentration of allylthiourea on speed, found quantities of allylthiourea effective from 10^{-6} up to 10^{-4} , beyond which speed decreased and fog increased excessively. It is very true that the optimum amount varies greatly with the nature of the emulsion, grain size, mode of addition, *etc.*, the last factor being particularly illustrated by the difficulties in sulphide sensitizing by bathing (19). But some recent experiments on the direct determination of silver sulphide formed in sensitizing a silver halide emulsion show that the upper limits of sensitivity material, estimated in Sheppard's experiments, are quite possible. The grains from an emulsion, after digestion with a gelatin containing labile sulphur, were separated by centrifuging in *three fractions*, large, medium and small. The large grains were of order $<2\mu$ in diameter, the medium about 1μ , the small 0.2μ and less. These grains were analyzed for silver sulphide by the method described by Sheppard and Hudson (20) with the following results:*

Size	Per cent. Weight of Fraction. Experiment I.	Grams Ag ₂ S per 1 gm. AgBr.
Large	72.2	5.95×10^{-4}
Medium	23.4	3.18×10^{-4}
Small	4.6	56.2×10^{-4}
	Experiment II.	
Large	50.0	7.4×10^{-4}
Medium	46.1	5.5×10^{-4}
Small	3.6	36.0×10^{-4}
Ultra-fine	0.24	105.0×10^{-4}

These determinations show first, that, as might be expected, the larger the surface to volume ratio, the greater the total amount of silver sulphide found per gram of silver halide. But also, in these experiments, in which actually a high degree of sensitizing was produced, the average amount of silver sulphide formed per gram AgBr, say 5×10^{-4} , is of the same order of magnitude as estimated from Sheppard's previous experiments.

It is also interesting to note that this is of the same order as the amounts of "Ursilber" found by Weigert and Lühr. Their conclu-

* My thanks are due to Dr. R. H. Lambert and Mr. H. Hudson for these analyses.

sion that this "Ursilber" was metallic silver and not silver sulphide was based entirely on solubility in persulphate, a criterion which I cannot regard as definitive for dispersions of silver sulphide so finely divided as would be in question. In any case, since we can demonstrate (a) presence in gelatin of "labile" (silver sulphide forming) sulphide sufficient to give Weigert and Lühr's "Ursilber" values, (b) presence on silver bromide grains of comparable amounts of silver sulphide, (c) removal from gelatin of comparable amounts of "labile" sulphur—it would seem that any demonstration of such quantities of metallic silver requires also analytical evidence of the absence of silver sulphide. We are proceeding at present to a comparison of Weigert and Lühr's silver determination with our method for determining "labile" sulphide and silver sulphide.

This question, viz., to what extent silver or silver sulphide forms the substance of "sensitizing specks" in a given case is, however, rather beside the present point, which is the discrepancy, on the basis of the data available, between the masses of "sensitizing specks" and of photo-silver respectively. This can be expressed broadly as:

	Mass per 1 gram AgBr in grams.	Molecules per molecules AgBr.
Photo-silver	10^{-10} to 10^{-7}	$1:10^{10}$ to 10^7
Sensitivity specks	10^{-6} to 10^{-4}	$1:10^5$ to 2×10^4

A concentration of photo-silver of 10^{-9} grams per 1 gram AgBr means only 50 to 60 atoms of silver in a grain of $1\mu^2 \times 0.1\mu$. Even supposing all these silver atoms present in a surface layer 2 molecules thick of ca. 10^7 molecules AgBr, the proportion of photo-silver atoms is extremely low. Any chance aggregate out of this would be very small compared with:

(a) The number of silver atoms supposed necessary to be aggregated to a particle large enough to form a developable nucleus—according to Zsigmondy and Svedberg around 300 atoms;

(b) The mass of silver sulphide sensitizing specks—the mass of photo-silver being estimated at about 10^{-5} to 10^{-2} of these.

If these principal conclusions prove correct they throw considerable doubt upon the hypothesis that the necessary and sufficient condition for developability of a silver halide grain is the presence of a silver nucleus of sufficient size. It is true that if the presence be assumed of silver "sensitivity specks" of size a few atoms below the critical limit (*cf.* argument of Eggert and Noddack already noted) the hypothesis can be formally saved. But if the sensitivity speck consists principally or entirely of silver sulphide, how can the addition or absorption of a very few silver atoms evolve a nucleus large enough for developability?

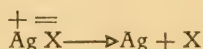
It has been shown recently by the writer and W. Vanselow (21) that silver sulphide nuclei can replace silver nuclei very effectively in catalyzing the thermal decomposition of silver oxalate. The reaction



proceeds rapidly at the interface $\text{Ag}_2\text{S}:\text{Ag}_2\text{C}_2\text{O}_4$, but naturally replaces this by the interface $\text{Ag}:\text{Ag}_2\text{C}_2\text{O}_4$. Since the total interface grows with time of reaction, the course is still autocatalytic, but the

induction is reduced and the velocity enormously increased by the presence of silver sulphide nuclei.

This strongly suggests that the essential for developability is *not* a nucleus of certain size, but one capable of properly anchoring sufficient silver atoms to start a unit cell of a silver crystal. This might be 16 or less. It has been suggested by E. R. Bullock (22) that "the unit of latent image (or latent fog) in its most effective usual form for chemical or physical development is a single silver atom at rest." Later (23) Bullock indicates Meidinger's results as supporting this conception. It is somewhat difficult to see why sensitivity nuclei, *e.g.*, of silver sulphide, should give *enhanced* sensitivity on this view, especially if chemical development is essentially a reaction in the solid phase (24). Hilsch and Pohl's results indicate that exposure of silver halides forms "centres" of photo-silver which are probably *not* monatomic, but also are not usually of high aggregation—over 100 atoms—since the absorption curves of the photo-silver are very different from those for colloiddally dispersed silver. On the other hand, the considerations herein advanced increase the pertinence of Bullock's criticism (25) of the hypothesis that minimum weight of size *per se* is "the necessary and sufficient condition for developability." The question has been discussed to some extent by A. Steigmann (26) with explicit reference to the question of minimum nucleus size for developability. This author does refer to "the catalytic state of the ripening nuclei," by which apparently he signifies both its presumed hydrogen-activating activity (according to Steigmann and Kögel's theory of sensitizing) but states that it has also the function of a "form catalyst, the task of which is to accelerate a localized crystal *growth** [on exposure], so that on quite short light reduction, that *magnitude*† is reached which is required for reduction catalysis in the developer." His discussion therefore still emphasizes the attainment of critical size of the developable nuclei, although a qualifying suggestion in regard to the sensitizing nuclei is made. The suggestion that minimum space lattice requirements were more essential than minimum size *per se*, seems to have been first clearly stated by H. J. Volger and W. Clark (27). In discussing the latent image and developability, they suggest "the condition be sufficient silver atoms in a group to form a *strong space lattice*." On following through this hypothesis it is not size of speck as such which is important for development, but aspect, *e. g.*, active edges which can orient and adlineate photo-silver atoms to initiate the silver lattice. From a wave-mechanic standpoint, the catalytic action of the specks might be limited to increasing the density of probability of states of equal energy of the systems.



and hence localizing or orienting the transition. On this view, *size* of sensitizing speck still retains an important rôle in the stage of exposure to light, since the chance of local concentration is increased.

* Author's italics.

† Writer's italics.

On the other hand, the fogging effect of excess of sulphiding agent might be owing to the probability of adlineation of stray silver atoms increasing with the mass, and particularly with the concentration (*i.e.*, size) of silver sulphide. The importance of the competition between sensitizing specks, as proposed by Sheppard, Trevelli and Loveland, and further developed by Sheppard (28), does not appear to be diminished by the foregoing considerations. The actual question of the relative amounts of silver and silver sulphide in sensitivity specks and in latent image specks respectively can only be attacked to a limited extent by chemical analysis, but this should be capable of deciding in certain cases whether the silver is far from equivalent to sulphur. Extension of Hilsch and Pohl's optical method to silver halide crystals containing silver and silver sulphide may also yield results of importance.

The considerations advanced in respect of the relative masses of "sensitivity specks" and "photo-silver" in the "latent image," if correct, lead to certain interesting conclusions. Apparently, in high-speed plates the "latent image" should be actually composed much more of silver sulphide than of metallic silver, although developability would be owing to accretion of this latter element. Further, the "nucleus bareing" action described by Lüppo-Cramer might consist as much (or more) in a reorientation or displacement of silver atoms (to form a lattice nucleus) as in actual "laying bare" or digging out of embedded nuclei. Also, the element of contingency or probability in photographic sensitizing is even more emphasized than when nucleus size was the sole variable considered. Size of nucleus becomes a *contingent* condition for securing sensitivity, rather than a necessary and sufficient condition; the probability of active silver lattices being formed increases with the size of the sensitivity nucleus.

Conclusion.—Recent determinations and calculations indicate that the number of atoms of photo-silver formed per gram of silver halide in latent image formation is too small to agree with previous "critical size" theories of nucleation. It is suggested that "aspect," or orientation of silver atoms to initiate a silver space lattice is a more essential function of sensitizing specks than mere size.

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STRAIGHT-LINE AND TOE RECORDS WITH THE LIGHT-VALVE*

*Donald Mackensie ***

IN ANY discussion of processing technic for sound records on photographic film, it is essential to keep in mind the distinction between the pictorial result desired and the object of sound recording, in order that preconceptions based on pictorial technic shall not be improperly transferred to the technic of sound reproduction.

It is the object of pictorial presentation to reproduce for the eye a wide range between highlights and shadows, together with acceptable gradations of the intermediate values of the scene photographed. The object of the sound film technic is to produce a positive transparency in which the projected transmission from point to point along the length of the film shall be proportional to the exposure of the negative at the corresponding point. This statement is applicable to the variable width as well as to the variable density track, provided we understand by "transmission" the light reaching the photoelectric cell from a given position of the scanning line on the sound track divided by the light from the scanning line direct. In the present discussion consideration is given exclusively to the variable density type of sound record and to the processing technics which have been proposed.

The requirements of pictorial reproduction have been thoroughly discussed by L. A. Jones,¹ who shows that faithful reproduction of brightness values is attained only when the over-all gamma is unity, with the further restriction that negative exposure and positive printing shall be confined to the straight-line portions of the respective H & D curves. In practice it is common to use an over-all gamma greater than unity and allow the positive print to intrude into the toe of the positive curve, for reasons depending on lens performance and conditions of screen illumination.

The requirement that the over-all gamma shall be unity and the positive and negative exposures shall be confined to the respective straight lines, forms the basis of the classical recommendations for variable density sound records where a light source is available which can give the desired negative exposure. Another processing technic for variable density sound records is based upon a suggestion by F. F. Renwick.² This involves toe exposure of the negative, developing the negative to a high gamma and printing it on a positive material similar to the negative material, using the positive toe and developing the print to the same high gamma as the negative. Such a procedure makes it possible to use positive emulsion with sources of restricted intensity and has been recommended even for the unrestricted light source.

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** Electrical Research Products, Inc., New York, N. Y.

Both of these processing methods are in practical use today, and it is the purpose of this paper to investigate the results obtained in the reproduction of sound by the two methods, incidentally establishing the sensitometric foundation more precisely than was possible some years ago.

It will be assumed that we have a light source capable of being modulated by electric currents so that the wave of light variation shall be a distortionless copy of the current wave modulating the light source. For the sake of definiteness in the discussion, we shall limit ourselves to the case where the light intensity is constant and the time of exposure varied by the current, although it will later be pointed out that the conclusions reached apply as well to the case of constant time of exposure and varied light intensity.

The two processing technics to be examined are popularly known as straight-line recording and toe recording, and it will be shown in this paper that excellent sound records can be obtained from each, provided certain requirements are met.

Sensitometric Scales

In any processing where uniformity of results is desired, sensitometric control of development of both positive and negative is necessary, whatever the type of sound record. The same control is necessary for uniformity of pictorial results, although in this case the trained eye has been used as a measuring instrument with fair success. For the sound record more impersonal measurements are required. Let us examine the sensitometric scales and the kinds of measurements involved.

Sensitometers are classified as time scale or intensity scale. In the time scale sensitometer the sensitometric strip is made by exposing successive areas of the film to successively increasing intervals of time. In the intensity scale sensitometer the successive areas of the strip are exposed for a constant time to increasing intensities of light. This light variation is accomplished by interposing between the light source and the film to be exposed a variable mechanical shutter or a step tablet of varying density.

The sensitometer scales which we take into account in film processing must be carefully distinguished as to the class in which they belong and the kind of light source used in the sensitometer. Furthermore, the kind of density measurements to be made on the developed sensitometer strip must be specified.

We have to distinguish the following types of sensitometric exposure:

(1) The daylight time scale of the Eastman Kodak sensitometer. This instrument uses as a light source the acetylene flame screened to daylight quality, and the sensitometer strip is exposed to a constant light of rather low intensity for intervals of time which become minutes at the maximum exposure. The exposure times increase in square-root-of-2 steps.

(2) The light-valve time scale of the Western Electric recording machine which exposes the negative to a light intensity of 100,000 meter-candles or more for times varying from 1/20,000 to 1/200,000 second. This recording machine uses a tungsten light source having a color temperature of about 2800°K.

(3) The intensity scale represented by the flashing lamps, where the time of exposure is about $1/20,000$ of a second and the light intensity varies up and down from 10,000 or 15,000 meter-candles. The specifications of light quality cannot be stated generally. This scale is not involved in the present discussion.

(4) The intensity scale of the printer, where the light source is usually a 60-watt tungsten lamp and the positive film is exposed through the negative. The time of exposure is about $1/40$ second and the intensity of light transmitted by the negative varies from a few score to a few hundred meter-candles.

The relations between the gammas derived from exposures on the above scales involve the failure of the reciprocity law and the dependence of gamma on the color of the exposing light. It is known, for example, that blue light gradations yield a lower gamma than gradations of yellow light and we may expect that, apart from failure of the reciprocity law, the daylight time scale gamma will be lower than the tungsten time scale gamma for the same development. The relation of printer intensity scale gamma to daylight time scale gamma will involve the color difference between tungsten and daylight as well as the difference between time scale and intensity scale exposures and the difference in source intensities.

Experiment has shown that for positive film in a given developer, the H & D curve for a definite gamma has the same shape at the toe, straight line, and shoulder, whether obtained by time scale or intensity scale exposure.* It has also been shown experimentally that for a given development time in the same developer the following ratios exist between the daylight time scale of the Eastman sensitometer and the light-valve time scale of the Western Electric recording machine, and between the Eastman scale and the tungsten intensity scale of the printer:

If the Eastman daylight time scale gamma = 1.00, then

- (1) the light-valve tungsten time scale gamma = 1.05
- (2) the printer tungsten intensity scale gamma = 0.95
- (3) the Cinex (tungsten time scale) gamma = 1.05

These ratios are derived from data collected for the purpose from most of the Hollywood laboratories that process variable density sound film. The values in the table apply to a wide range of positive and negative gammas.

The intensity gradations of the printer scale are understood to be gradations of effective printing densities of the negative printed. The significance of this specification will be made clear in what follows. H&D curves are customarily plotted with visual ** densities as ordinates against logarithms of exposure as abscissas. Exposures are given in meter-candle-seconds, and densities are measured visually by the polarization photometer head (or equivalent) with diffuse illumination of the film area being measured. In the Bell & Howell back-shutter printer, the light source sends light to the negative through two apertures in a line, and so the illumination is to some extent specular. Moreover, unless the negative being printed is neutral in spectral transmission, its density as appreciated by the positive emulsion will differ from its visual density by reason of the difference in spectral response of the film and the eye. The ratio of printing density

* We exclude from consideration sensitometers using extremely low intensities of illumination.

** "Visual" means in every case "visual diffuse."

to visual density will depend upon the spectral selectivity of the photographic deposit, and this ratio will combine with the specularity of the printing light to yield a printing coefficient for the negative which includes the color coefficient as ordinarily understood and the geometry of the printing operation. The printing coefficient may be equal to, less than, or greater than unity.*

Filters introduced in printing the sound negative alter the quality of light falling on the negative. This may affect the negative printing coefficient at the same time that the color change affects the gamma to which the positive is developed. The two effects may be opposed: one case was found where they cancelled each other, and the filter served merely to reduce the light as would a neutral gray.

Replacing the 60-watt tungsten lamp by a 200-watt, gas-filled lamp and suitable filter has been tried by one laboratory in Hollywood. The effect was a 12 per cent reduction in over-all gamma in addition to a reduction in exposure.

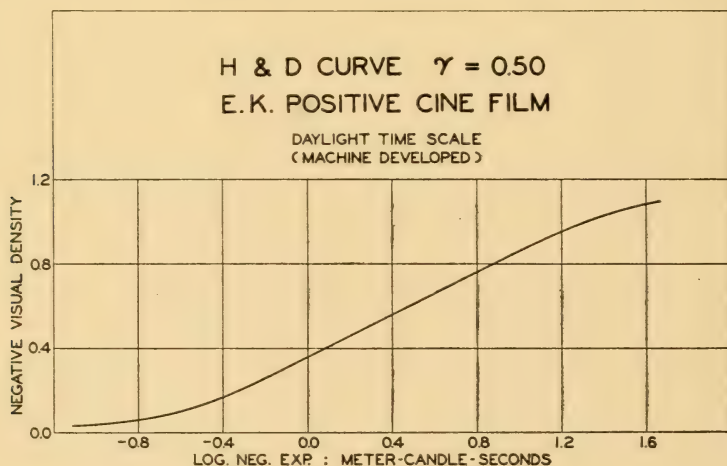


Fig. 1. Sound negative development.

Sensitometric Results

The accompanying figures will illustrate the foregoing. Fig. 1 is an H & D curve on Eastman positive emulsion, obtained with the Eastman time scale sensitometer, and developed in a sound negative bath to a gamma of 0.50. Visual diffuse densities are plotted against log meter-candle-seconds. The same development would be expected to give a gamma of 0.53 for light-valve exposures, where visual diffuse densities would be plotted against log valve spacings. A slightly shorter development would give a light-valve gamma of 0.50 and, as stated above, the resulting curve would register with the curve of Fig. 1.

* For determination of color coefficient see reference No. 3.

Values of printing coefficient ranging from 1.0 to 1.4 have been found. The printing coefficient is the ratio of gradations of effective printing densities to gradations of visual diffuse densities of the negative. Admitting the possibility of reflections from the negative in the printer which differ from those occurring in the visual diffuse densitometer, we can write:

$$\text{Effective printing density} = A + (\text{visual density} \times P.C.)$$

The effect of the constant A is a shift parallel to the density axis without change of shape, and thus is equivalent to a change in light intensity in the printer lamp. The $P.C.$ for the sound negative bath which produced Fig. 1 was 1.2; the effecting printing gamma then was 0.60.

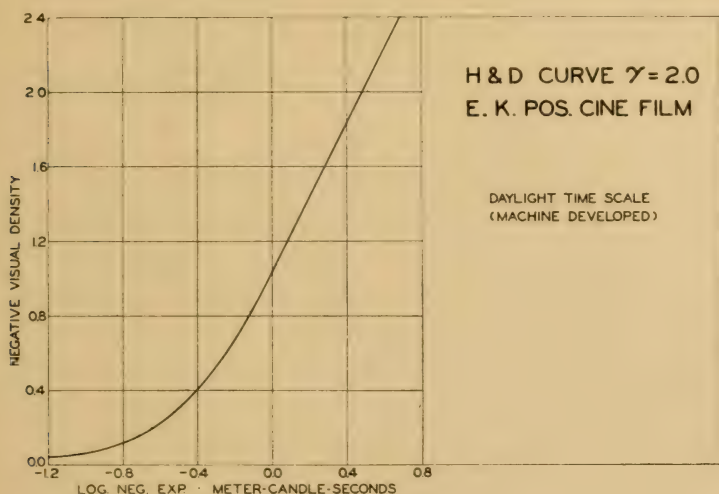


Fig. 2. Composite print development.

Fig. 2 exhibits the H & D curve of gamma 2.0; it is an Eastman time scale strip developed at the Fox Laboratory in Hollywood in the positive bath which serves for the sound negative and for the Movietone print. The printing coefficient of the negative was found to be 1.2. The method of determining $P.C.$ is described in connection with the next figure.

Fig. 3 is a plot of print visual density *vs.* negative visual density in the Fox processing. A negative sensitometer strip, the visual densities of which were carefully measured, was spliced into a loop of clear film and printed at printer points 3, 6, 9, 12, 15, and 18. Prints made with the 60-watt lamp with no filter at points 6, 12, and 18 are represented in Fig. 3. Similar prints obtained with No. 39 filter and a ground glass gave curves of the same shape. The net effect of the filter and ground glass is to reduce the light; the change in printing coefficient due to the filter is offset by the reduction in print gamma due to the change in light quality.

Unless there is a variation in gamma with printer point, the shift of printer point is equivalent merely to shifting the range of negative densities to cover successive (and overlapping) portions of the whole printer curve. To obtain Fig. 3, the print visual density was plotted against the negative visual density for each printer point separately, and the plots were brought into register by appropriate shifting along the axis of negative visual density. Fig. 3 gives no indication of a variation in gamma with printer point; this result has been confirmed on every printer so far examined, provided accurate density measurements are made on the negative loop and on the positive prints.

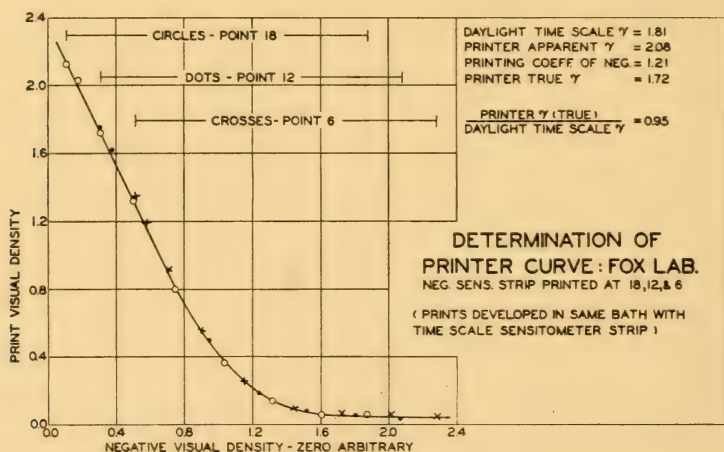


Fig. 3. Apparent printer characteristic.

Study of Fig. 3 shows that a change of 3 printer points is equivalent to a shift of 0.10 along the axis of negative visual density. This is confirmed by all the prints made of this negative: the print at point 6 registers with that at point 18 when shifted 0.40 in visual density. It is known from illumination measurements at the printing gate of the Bell & Howell back-shutter printer that between points 3 and 18 there is a linear logarithmic relation between printer point and meter-candles at the gate; a change of 12 printer points means a change of 0.48 in log meter-candles. A change in visual density of 0.40, therefore, is equivalent to a change of 0.48 in log effective exposure; the printing coefficient of this negative then is 1.2.

While this determination lacks precision both in the illumination measurements and in the registrations of the different print curves, it checks closely with the relation previously stated between the daylight time scale gamma and the printer intensity scale gamma. It will be recognized that a curve plotted between print visual density and negative visual density will give an apparent printer gamma higher than the true, if the P.C. of the negative is greater than unity. The gradations of negative density should be multiplied by the nega-

tive *P.C.* to obtain the true gradations of effective exposure on the positive material. When this is done the true printer gamma is seen to be less than the apparent in the ratio of the *P.C.*

If the daylight time scale gamma is γ_T then the true printer

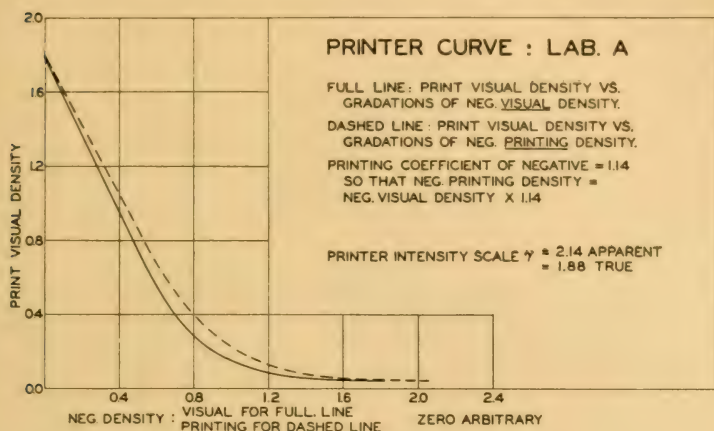


Fig. 4. Negative printing coefficient equals 1.14.

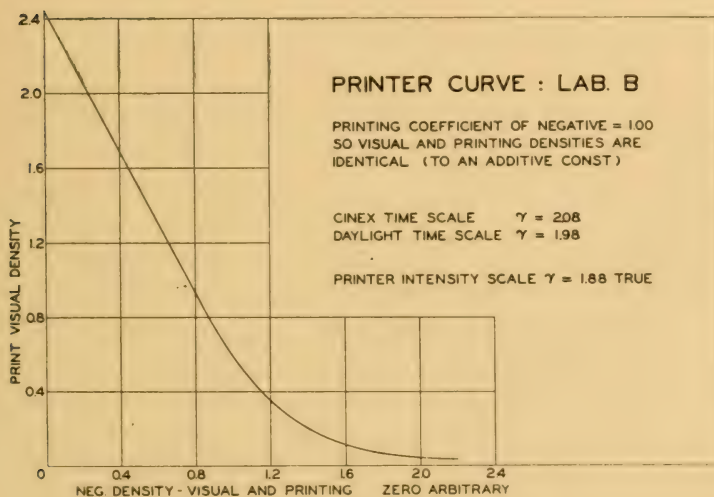


Fig. 5. Negative printing coefficient equals 1.00.

gamma is $0.95 \gamma_T$ and the apparent printer gamma (print visual density vs. negative visual density) is $0.95 \gamma_{TX}$ neg. *P. C.* From the data shown in Fig. 3, the *P.C.* is 1.21.

The relation just stated between printer intensity scale and Eastman time scale gammas serves to reconcile the results of printer studies at five laboratories in Hollywood. These laboratories use differ-

ent formulas for the sound negative developer. Four of them use the Bell & Howell back-shutter printer with no modification of printing apertures. The negative printing coefficients thus differ from one laboratory to another, and curves from two of these laboratories (referred to as "A" and "B") are shown in Fig. 4 and Fig. 5.

Fig. 4 is a curve obtained in the same way as Fig. 3 by consolidating the individual curves at separate printer points. The sound negative printed in this series of measurements had a printing coefficient of 1.14. The curve of Fig. 5 is similarly obtained from studies in laboratory "B", where the sound negative had a faint magenta color and its printing coefficient was 1.0. This value is indicated both by the registrations of separate print curves and by taking into account the ratio 0.90 between the Cinex time scale gamma and the printer intensity scale gamma.

The positive formula at laboratory "A" was at this time the same as at laboratory "B" except that a small amount of citric acid was present in one of them. Since the printers are the same, and the positive prints were developed in the same type of developer to the same contrast as read by the sensitometers (taking into account the ratio of the sensitometer scales at the two laboratories) we should expect that the true printer curves, each corrected for negative printing coefficient, would be identical in shape and would register on each other. The shift along the axis of negative printing density required to effect this registration is due to the difference between the arbitrary zeros of Fig. 4 and Fig. 5. The agreement between the two curves when so treated is shown in Fig. 6. Here one set of points is the curve of Fig. 5, requiring no correction for printing coefficient. The other set is taken from the curve of Fig. 4, the corresponding negative visual gradations having been multiplied by 1.14, the negative printing coefficient at laboratory "A".

We may then take the curve of Fig. 6 to be the true printer curve for this positive formula and for the standard printer when the Cinex time scale gamma is 2.08. The ordinates of the curve are print visual densities. The abscissas are negative printing gradations. Therefore, if it is desired to construct the apparent printer curve in this developer at this time of development for any other negative printing coefficient than unity, the abscissas of Fig. 6 need only be divided by the negative printing coefficient under consideration. The development to a positive contrast of 2.08 by Cinex or 1.98 by daylight time scale is one which is commonly used for picture prints and, therefore, also for the sound print of the composite film.* It will be noticed that this value of daylight time scale gamma differs by only 1 per cent from the Fox positive processing represented in Fig. 2. Errors no greater than 1 per cent can scarcely be avoided and it is safe to say that the curves of Figs. 2, 4, and 5 belong to the same developed contrast. Besides this, the shapes of the toes of the three curves, when printing coefficients are eliminated, are found to be substantially identical.

* In Hollywood studios there is a recent tendency to lower print gammas.

A common value of the negative printing coefficient is 1.2. Equally common is the positive contrast of 2.0 by the daylight time scale. Having now the true printer curve for this daylight time scale positive gamma, we can construct an apparent printer curve between print visual densities and negative visual densities which will be representative of the processing of Fig. 2. and of the results at laboratories "A" and "B" of printing a negative whose printing coefficient is 1.2.

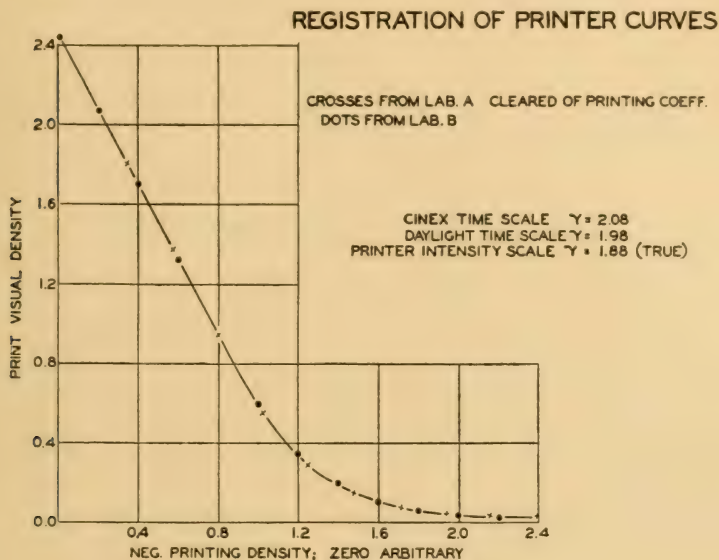


Fig. 6. True printer characteristic.

The Projection Factor

At this point it is appropriate to introduce the relation between projected print density in the reproducing sound head and visual print density measured on the densitometer. Data relating projected and visual densities of various samples have been collected at numerous times, and it has been usually found that the ratio of projected to visual density is not a constant but increases at the lower values of density.

This matter is discussed by Tuttle and McFarlane,⁴ who tabulate values of visual diffuse density and of reproducer density for positive film. In their work the reproducer density was measured by a galvanometer in series with the potassium cell. Similar measurements of densities were made at the Fox laboratories in the course of the present work. In Fig. 7 are shown plots of the data obtained in these measurements and of the data tabulated by Tuttle and McFarlane. It will be observed that to the points in both plots straight lines of the same slope can be fitted, intersecting the axis of projected density at a point to the right of the origin. The data are represented by the equation:

Projected print density = $K + (1.22 \times \text{visual print density})$

where K has the values 0.03 and 0.04, respectively, for the Fox data and for the Tuttle and McFarlane data.

The existence of this constant K may be attributed to reflection of light at the burnished surface of the print. Similar measurements on specimen photographic densities not burnished show a straight line passing nearly through the origin, the value of K being 0.01 and the slope 1.25. These specimens were obtained from the Eastman Kodak Company in Rochester and were developed according to their own formula.

The reflection of light from the emulsion surface in the sound head is undoubtedly different from the reflection in the visual densitometer where the emulsion lies just above a diffusing surface. The plots of Fig. 7 indicate reflections of 7 and 9 per cent, respectively, if the constant K is identified with this effect.

VISUAL DIFFUSE VS. PROJECTED DENSITY

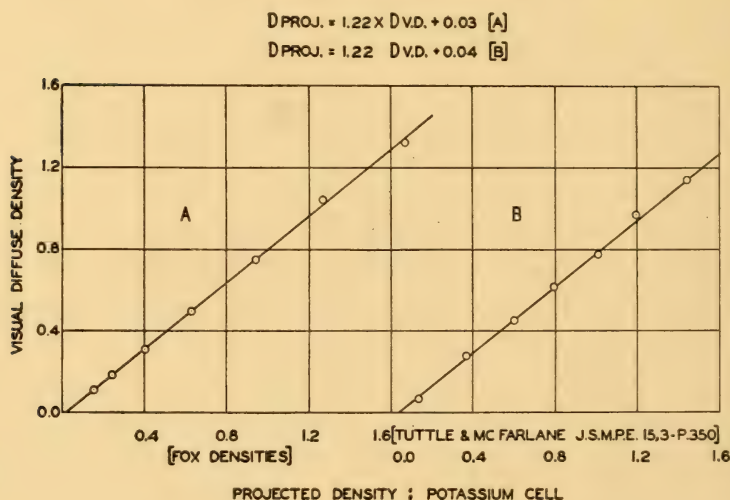


Fig. 7. Projection factors.

The existence of an additive constant in projected density implies merely a displacement along the axis of projected print density and involves no change in shape of the curve. This additive constant becomes a multiplying constant when projected transmissions are taken instead of projected densities and so is equivalent to a slight reduction in the light from the reproducing lamp. It is, therefore, justifiable to multiply print visual densities by a constant to obtain projected print densities. This constant, hereinafter called the "projection factor," involves the specularity of the reproducing illumination and the difference in spectral response between the photoelectric cell and the eye. The projection factor thus is allied to the negative printing coefficient.

It is known that projected densities for the potassium cell are somewhat lower than for the caesium cell. In a particular case investigated some time ago, the reproducer densities using the Western Electric potassium cell were 6 per cent less than when using the Western Electric caesium cell. A convenient compromise, nearly correct for both potassium and caesium cells, is obtained by taking 1.25 as the ratio of projected to visual gamma. On this basis it is possible to construct a curve based on Fig. 6, multiplying the print visual densities by 1.25 and dividing the negative printing densities by 1.2. The resulting curve is the projection characteristic of prints from a negative having a printing coefficient equal to 1.2, the print development being carried to a daylight time scale gamma of 2.0.

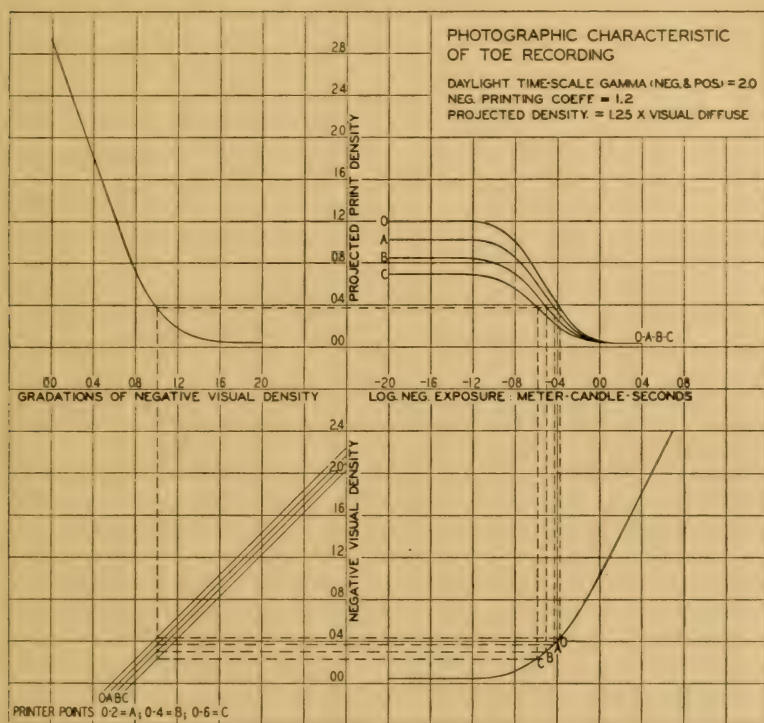


Fig. 8. Toe recording construction.

Characteristics of Toe Recording

In Fig. 8 a graphical construction adapted to the use of the data which have been presented shows the photographic characteristic of toe recording. In the lower right-hand quadrant of this figure is replotted the curve of Fig. 2. In the upper left-hand quadrant is plotted from Fig. 6 the curve of projected print densities vs. gradations of visual negative density, using the projection factor 1.25 and the printing coefficient 1.2. Choosing any point on the negative H & D curve and the projected print density to which this point shall

be printed, we determine the construction by drawing a horizontal line through the chosen negative density in the two lower quadrants and a vertical line in the upper and lower left-hand quadrants through the print curve at the chosen projected print density. Through the intersection of these lines in the lower left-hand quadrant a straight line at 45 degrees is drawn to represent the printer point. A vertical line through the chosen point on the negative curve intersects a horizontal line through the chosen positive projected density and locates a point of the over-all curve in the upper right-hand quadrant.

The oblique line in the lower left-hand quadrant serves to transfer the negative densities to the scale of negative visual gradation on the horizontal axis at the left. The location of this line determines the portion of the positive projected density curve which shall be covered by the range of negative densities of the sound record. Remembering that the printing coefficient of the negative is 1.2 and that a difference in negative visual density of 0.10 is equivalent to a change of 3 printer points, we can locate 45 degree lines in the lower left-hand quadrant corresponding to any desired number of printer points above or below the line we start with. For the sake of illustration, four such printer point lines are drawn in Fig. 8 at intervals of 2 printer points. The dashed horizontal lines in the two lower quadrants determine the negative exposures which will be printed to the same projected print density by the appropriate printer lines. For each printer point the rest of the construction follows immediately giving the over-all photographic characteristics *O*, *A*, *B*, and *C* of the upper right-hand quadrant.

The printer curve of the upper left-hand quadrant is reversed left and right from the usual plotting of such data in order to show more clearly the effect of the positive toe. All four of the over-all curves terminate to the left in horizontal lines which show the effect of printing the negative fog density, and on the right they terminate in a horizontal line, the same for all four curves because of the positive fog. Photographically considered, these curves are by no means suited for pictorial reproduction in as much as the range between highlights and shadows is limited and the range of negative exposures which show gradation in the final print is narrow. The processing represented by Fig. 8, therefore, gives a poor picture. How well it serves for sound reproduction cannot be clearly seen from this plot, and we require a plot of projected print transmission *vs.* negative exposure.

In Fig. 9 the four over-all curves of Fig. 8 are replotted in arithmetical terms. It will be seen that in each of the four curves of Fig. 9 there is a region where the curve is nearly straight. Heavy dots indicate the limits of approximately linear reproduction and the proper average transmission. It must be recognized that the curve is nowhere ideally straight but is S-shaped, with a point of inflection, on each side of which the departure from a straight line is small enough to be ignored within a certain range of negative exposure. The object of sound-record processing is to select a negative exposure and a printer point such that the departure from linearity shall be small and

symmetrical on both sides of the exposure selected, whenever strict linearity is not attainable.

Printer point C (Fig. 9) clearly shows an approximately straight portion much shorter than printer points O, A, and B. The straight-line portions for O, A, and B are of approximately the same length, the centers being at nearly the same projected print transmission, but corresponding to different values of unmodulated negative exposure. A print at 2 printer points above O would no doubt be equally successful, but a print 2 points darker still would undoubtedly show limitations as great as those of C.

The curves definitely suggest that equally good results are to be expected from unmodulated negative exposures between 0.30 and 0.45 meter-candle-seconds, provided the printer points are so chosen that the projected positive transmission shall be the same for all these negatives—namely, about 42 per cent, corresponding to a visual print

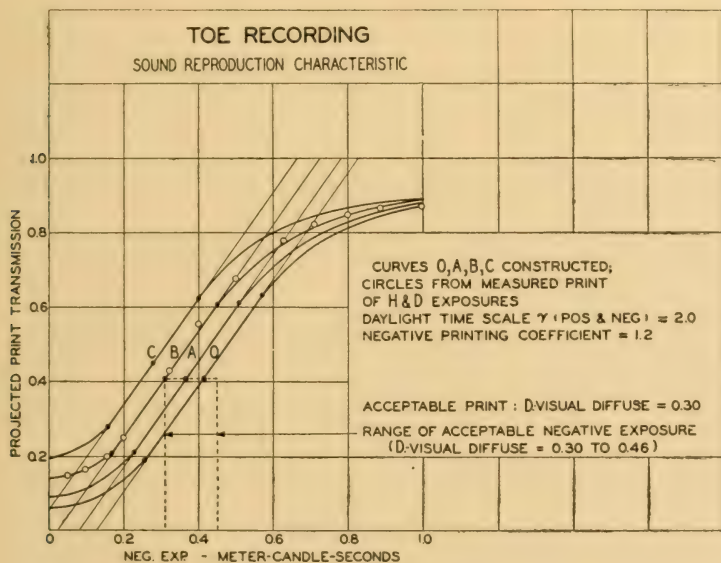


Fig. 9. Toe record positive.

density of 0.30, visual transmission 50 per cent. For negative exposures within these limits of permissible variation the modulation of the sound record should be restricted to 40 or 50 per cent, in order that the maximum and minimum negative exposures shall not sensibly encroach on the definitely curved upper and lower ends of the over-all curves. Within this range in the choice of negative unmodulated exposure, restricting the modulation as indicated, and choosing the printer point for a projected positive transmission of 42 per cent, we obtain prints of substantially equal volume. The amplitude of photoelectric cell current is determined by the swing in transmission corresponding to the swing in negative exposure, and it is seen that in curves O, A, and B the swing in transmission is about 44 per cent.

The proponents of toe recording for sound records have usually advocated a negative visual transmission of 50 per cent, printed to a positive visual transmission of 50 per cent, with negative and positive gammas as in Fig. 8. It appears from the preceding discussion that the unmodulated negative transmission is not limited to this value although the appropriate printer point yields the same positive transmission for each negative unmodulated exposure within the permissible range.

Based on the above conclusions, a toe record on Eastman positive film was made with the light-valve, setting the recording lamp to result in an unmodulated track density of 0.30 visual diffuse when the negative is developed to a daylight time scale gamma of 2.0*. Following the usual recommendations for toe records this was printed to a positive track density of 0.30 visual diffuse, the print being developed as had been the negative. These requirements were exactly met at the Fox Laboratory.

A daylight time scale exposure on the negative was printed through on the positive. The printed-through densities were measured and converted to projected densities by the projection factor, 1.25. This over-all curve in terms of projected print density *vs.* log negative exposure in meter-candle-seconds was translated into projected print transmissions *vs.* negative exposures and the open circles in Fig. 9 show how closely the actual result agreed with the expected. Perfect agreement would locate the circles on the curve in Fig. 9 at printer point B. This check appears satisfactory to vindicate the construction employed and the considerations on which it is founded. The record showed excellent quality for both speech and music.

Limitations of toe recording remain to be discussed, but the emphasis at this point is upon the fact that, by properly choosing the negative exposure, negative modulations, and printer point, a processing which is pictorially useless gives a result which is acoustically excellent.

A claim made for toe recording is that the sound negative, when projected, is of as good quality as the print to be made from it. In Fig. 10 the negative curve in the lower right-hand quadrant of Fig. 8 is replotted (taking account of the projection factor) in terms of projected negative transmission *vs.* negative exposure. No part of this curve is straight.

The foregoing discussion of toe recording has made use of H & D curves derived from time scale exposures, whereas the flashing-lamp records give intensity scale variations of exposure on the negative. In the region of the negative characteristic to which the toe exposures are confined, the difference in shape for the same development between intensity scale and time scale exposures is so small as to be negligible and the conclusions stated above apply substantially to either type of negative modulation.**

* The light-valve gamma would be a little higher than the daylight gamma, but the shapes of the toes would not differ appreciably.

**In the Fox development, daylight time scale strips or gammas of 1.81 and 2.15 show toes which do not differ in shape below a visual density of 0.80. It is not likely that the flashing-lamp gammas would differ more than 10 per cent from the daylight time scale gamma, and it has been mentioned that an intensity scale curve coincides with a daylight time scale curve of the same gamma. There remains the chance that a different negative exposure would be required to give the desired negative density.

Characteristics of Straight-Line Recording

Before studies were made of the negative printing coefficient, projection factor, and relations between sensitometric scales, the curves of Fig. 1 and Fig. 2, where the negative gamma is 0.50 and the positive 2.0, would have appeared to define a sound record processing in conformity with the classical specifications of an over-all gamma of unity. As a matter of fact, such processing can be used successfully for the reason that the positive development represented by Fig. 2 is suitable for the picture prints, and a development corresponding to Fig. 1 can be readily provided for the sound negative on positive emulsion.

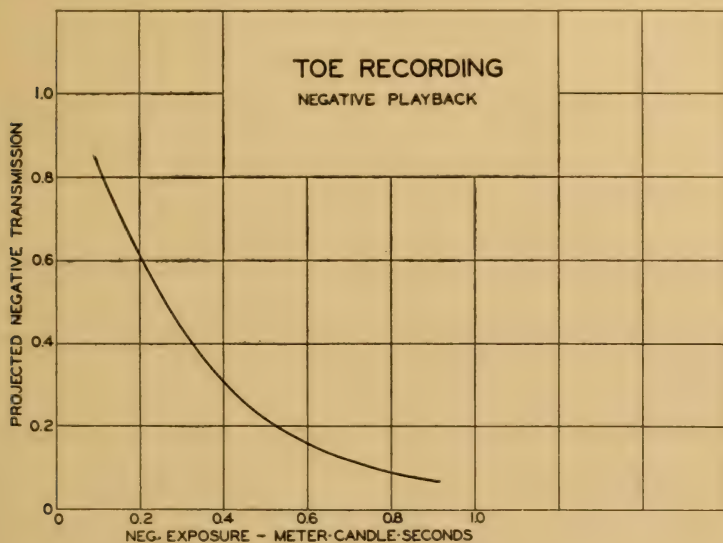


Fig. 10. Toe record negative.

Taking into account the projection factor, the negative printing coefficient, and the relation of true printer gamma to sensitometer gamma, we can enumerate the factors which enter into the determination of the over-all projected gamma. They are as follows:

- (1) the light-valve gamma, derived from the curve plotted between negative visual density and log light-valve spacing;
- (2) the apparent printer gamma, derived from a plot of print visual density vs. negative visual density;
- (3) the projection factor, depending somewhat on the type of cell and the structure of the sound head. This factor has been taken as 1.25 for reasons given above.

The over-all gamma is the product of the light-valve gamma times the apparent print gamma times the projection factor. It is this triple product which should be unity in order strictly to conform to classical requirements. The apparent printer gamma must be determined by making prints of the actual negatives for which the light-

will not reduce the exposure beyond the lower limit, nor increase the exposure as far as the upper limit of the straight line. The importance of being able to use a high modulation of negative exposure will be evident when we come to discuss noise reduction.

Fig. 11 exhibits an over-all construction on the same basis as that in Fig. 8, except that the lower right-hand quadrant is occupied by the curve of Fig. 1. Printer lines are drawn such that for one of them a negative unmodulated exposure equal to 10 times the toe exposure shall appear as a positive projected density of 0.75; for the other, an unmodulated negative exposure 6.3 times the toe exposure appears also as a positive projected density of 0.75.

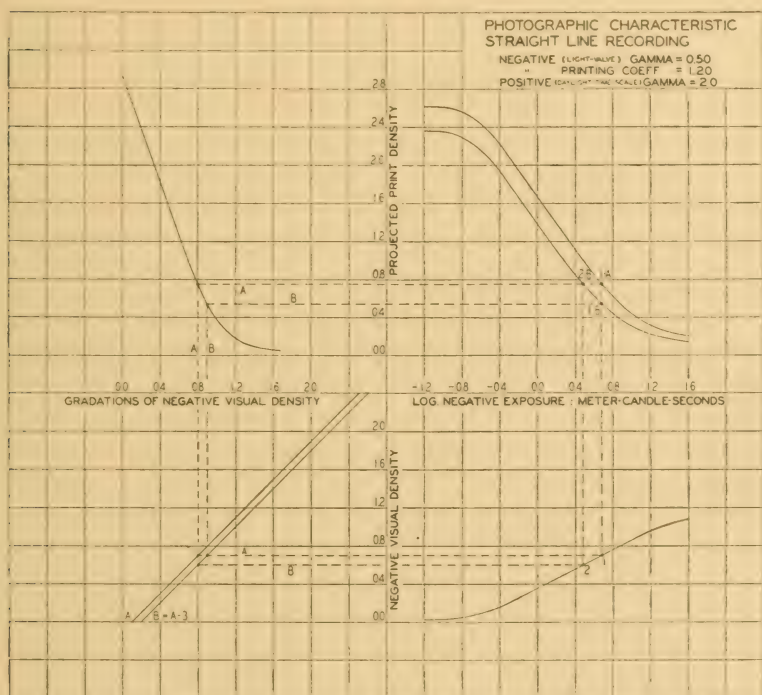


Fig. 11. Straight-line recording, over-all gamma = 1.4

The processing represented by Fig. 11 is commercially practicable and produces successful sound records. The over-all print curves in the upper right-hand quadrant are also adapted to pictorial requirements; in this case the sound is not in conflict with the picture.

The final print curves of Fig. 11, translated into projected print transmission *vs.* negative exposure, are drawn in Fig. 12. For convenience the negative exposure is given in terms of the toe exposure. Just as in Fig. 9 in toe recording, we find here an S-shaped curve in-

cluding a fairly straight portion. Curve *A* has this straight portion centered at a negative exposure equal to about 10 times the toe exposure, appearing as a positive projected transmission of 17 per cent. The central exposure of the straight-line part of curve *B* is about 6 times the toe exposure and again corresponds to a projected transmission of 17 per cent. We see here a point of resemblance between toe recording and this approximation to straight-line recording. In toe recording the negative exposure can vary from 0.30 to 0.45 meter-candle-seconds and produce a successful sound record, if the unmodulated negative exposure is in each case printed to a positive projected transmission of 42 per cent. In the straight-line record the negative unmodulated exposures may vary between 6 and 10 times the toe exposure, provided the projected transmission of the unmodulated positive track is made 17 per cent. Whereas in the toe record negative modulation must be restricted, say, to 45 per cent, in the recording represented by Fig. 12, 70 per cent negative modulation can be used without overstepping the straight-line limits of the final curve.

The two curves of Fig. 12 show approximately the same volume for 70 per cent modulation of the average negative exposure. This volume is proportional to 0.27 (average of *A* and *B*) whereas the volume of the toe record is proportional to 0.44 (Fig. 9), a difference in output of 4.2 db. in favor of the toe record.* Offsetting this is the difference between the projected noise levels to be expected from the unmodulated positive tracks of the two types of record. Within the limits of 10 and 40 per cent projected unmodulated transmission the noise amplitude, combining the noise contributions of negative and positive, is proportional to the projected positive transmission. There is indicated for the toe record a noise level 7.8 db. higher than that of the straight-line record. This difference corresponds to the 42 per cent transmission of Fig. 9 compared with the 17 per cent transmission of Fig. 12.

For both types of record the tolerance of negative unmodulated exposure may be interpreted as a tolerance in emulsion speed or in bromide concentration of the developer, or in intensity of light source. From the point of view of the negative record it is, strictly speaking, a tolerance in the location of a point on the H & D curve.

Application of Noise Reduction

The standard noise-reducing equipment closes the light-valve to a predetermined spacing when there is no input signal. When a signal current arrives at the light-valve terminals, provision is made to increase the spacing sufficiently to accommodate the incoming signal with adequate margin. It is not the purpose of this paper to discuss the adjustment of noise-reduction equipment, but to inquire what noise reduction may be expected of toe and of straight-line records without impairment of quality. The requirement should be adhered to that the negative exposure shall not fall below the limit of the straight-line of projected print transmission *vs.* negative exposure.

* 4.6 db. if we are generous to the circles of Fig. 9.

As a basis for comparison let it be assumed that the valve closure shall in each case be such that an incoming signal 20 db. below the level, which fully modulates the valve at its standard spacing, shall not drive the negative exposure below the straight-line limits of Fig. 9 and Fig. 12, even if the noise-reduction equipment should fail to reopen the valve as rapidly as this incoming signal demands. At the normal valve spacing of 1 mil a sine-wave signal causing 100 per cent modulation changes the valve spacing by 1 mil above and below its unmodulated value. A sine-wave signal 20 db. lower than this full modulation opens and closes the valve by 0.1 mil, and it is this rapid movement in closing which must not reduce the negative exposure below the prescribed limit.

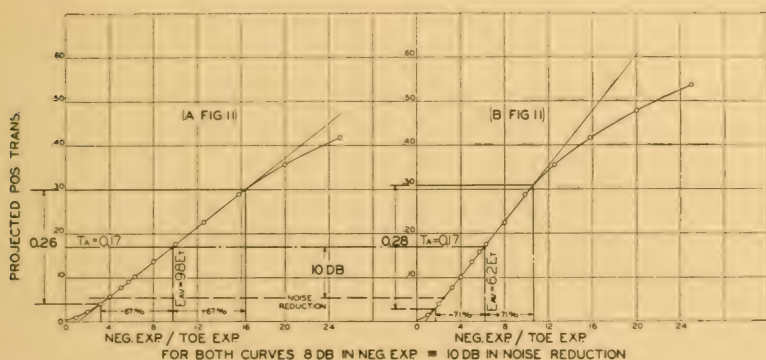


Fig. 12. Straight-line recording; sound reproduction characteristic.

In the toe record, where 45 per cent modulation of negative exposure is permissible, the noise-reduction device may close the valve spacing to 0.65 mil, in which case a further decrease in spacing of 0.1 mil will not go outside the straight-line limit. Examination of the curves of Fig. 9 shows that this closure of the unmodulated valve spacing to 0.65 mil brings about a reduction in positive projected transmission equivalent to lowering the projected noise level by 6 db.

Treating the curves of Fig. 12 in the same way we find that closing the normal 1 mil valve to 0.4 mil is permissible, since a further closure of 0.1 mil just reaches the lower limit of the straight line. This is an 8 db. reduction in valve spacing and results in a 10 db. reduction of projected print transmission. It is therefore concluded that a noise reduction of 10 db. is possible in the composite* processing represented by Fig. 11 and Fig. 12.

The above conclusion regarding straight-line recording of this type has been often verified. Experimental toe records with the light-valve were made with adjustments of the noise-reduction equipment resulting in 9, 10, and 11 db. reduction of projected noise, showing

* By "composite" is meant the processing of the sound positive to an over-all gamma greater than unity, in part offsetting this by appropriate use of the positive toe, the negative exposure being confined to the straight line.

in each case a distinct deterioration in quality and distortion of volume relations. These experiments roughly substantiate the statement that a 6 db. reduction in noise is all that can be expected of the toe record without incurring quality loss.

Compared with the straight-line the toe record has the advantage of greater signal volume, but this is offset by its narrower range between signal and noise level without noise reduction, and the smaller amount of noise reduction applicable without distortion.

In actual projection, the experimental toe record without noise reduction was found to be more than 1 fader step and less than 2 steps louder than composite straight-line records of the type here described. For the same level of dialog projection the ground noise of the toe record was somewhat more than 1 fader step louder than the ground noise of the straight-line record. Volume indicator measurements of dialog level and ground noise level showed for the toe record a range of 24 db. between dialog and noise. If we can take 8 db. as the logarithmic difference between voice peaks and general voice level as read on the volume indicator, we have a range of 32 db. between the limiting swing of positive transmission and the ground noise amplitude. This is an amplitude ratio of 40 to 1. If the double amplitude of modulation of projected positive transmission is 0.44, then the double amplitude corresponding to the ground noise is 0.011. This is a variation of less than 3 per cent of the average projected transmission shown in Fig. 9. If the noise were due exclusively to the film itself the variations in transmission corresponding to the ground noise would be almost imperceptible to the eye.

Classical Straight-Line Records: Over-All Gamma = 1.0

In the composite straight-line record of Fig. 11 and Fig. 12 the indicated limits of negative exposure in both curves *A* and *B* are within the limits of the straight-line part of the *H & D* curve. The over-all gamma is 1.4 and by itself would result in a curve of projected print transmission increasing more than proportionally to the negative exposure. This curve, convex to the axis of negative exposure, is partially rectified by printing on a portion of the positive toe. No use is made of the negative toe; this would exaggerate the convexity of the curve as the lowest negative exposure.

An over-all projected gamma of unity would result from a negative light-valve gamma of 0.36 in place of the negative curve of Fig. 11. The classical specifications require that the only straight-line part of this curve be used for the negative exposure and that it be printed to lie wholly within the straight-line part of the projected print curve.

Since for a Cinex gamma of 2.1 the printer curve is seldom straight beyond a visual density of 2.4, the maximum scale of negative densities printable on the positive straight line is 0.74 (see printer curve of Fig. 8 or Fig. 11). For 90 per cent modulation of negative exposure, confined to the straight-line portion for gamma

$= 0.36$, the negative density range is $0.36 \times \log 19 = 0.46$. There is, therefore, a latitude of 8 printer points in printing this negative: $0.74 - 0.46 = 0.28$, and 3 printer points correspond to 0.10 in negative visual density for a printing coefficient of 1.2.

Fig. 13 shows the projected printer curve rotated 90 degrees to the left and negative lines of slope 0.36. These lines are of such length as to cover a range of 1.28 in log negative exposure, corresponding to 90 per cent modulation of a central exposure equal to 10 times the toe exposure. The actual H & D curve of gamma $= 0.36$ begins to be straight at a visual density of 0.14; for convenience the lines drawn in Fig. 13 are located to represent the lowest and highest printer points at which they can be printed without going outside the straight part of the printer curve.

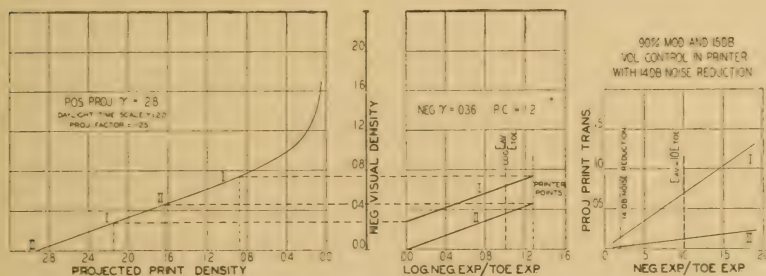


Fig. 13. Classical straight-line recording.

At the right in Fig. 13 are the corresponding curves of positive transmission *vs.* negative exposure for the limiting printer points. Each of these curves is straight over 90 per cent modulation of the central negative exposure indicated. Comparison of the two curves shows the unmodulated positive projected print transmissions to be 0.07 for the lightest print and 0.012 for the darkest print consistent with the requirement that the negative shall be printed on the straight-line part of the printer curve. The volume difference between these two prints is therefore about 15 db. The maximum permissible noise reduction is determined by the requirement that a signal 20 db. below full modulation of the normal valve spacing shall not cause the negative exposure to fall below the toe exposure; 14 db. reduction in valve spacing closes the valve to 0.2 mil. This is the maximum permissible and corresponds to 14 db. reduction in ground noise.

The signal volume to be expected from the lighter of these prints is more than 6 db. lower than the volume obtained from the composite record of over-all gamma $= 1.4$ and negative modulation 70 per cent. At the same time the noise level is more than 7 db. lower (unmodulated projected transmission of 0.07 compared with 0.17). The volume range between signal and noise is therefore about 1 db. greater in this record than in the composite.

Projection Levels of Light-Valve Records

The types of light-valve records discussed may be called toe, composite, and classical. Each with its appropriate negative exposure, negative modulation, and printer point is capable of giving excellent sound reproduction. Only with the third type, the classical record, is it possible to control signal volume over a considerable range without distortion by choice of printer point. This will be clear from an examination of Fig. 9 and Fig. 12. It will be evident that for both toe and composite types, varying the printer point on a given average negative exposure will involve distortion unless the negative modulation has been narrowly restricted. For practical reasons only the lightest possible print of the classical record would be produced for theatre use.

The numerical estimates of signal volume given for the three types of record show the toe record to be approximately 1.5 fader

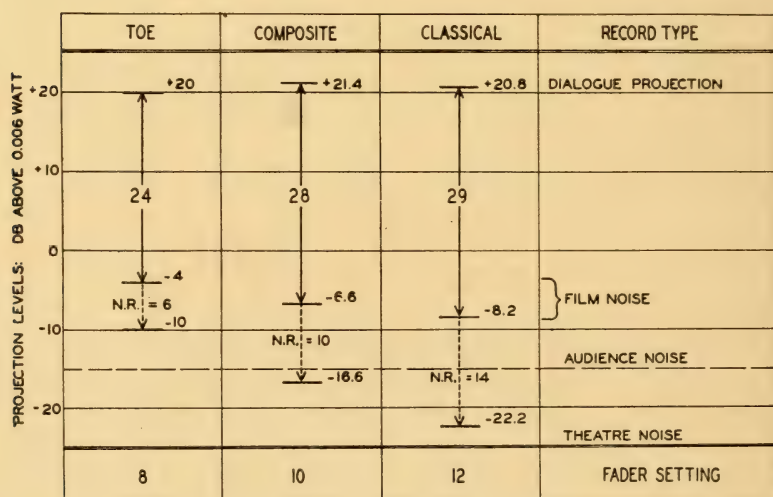


Fig. 14. Projection levels. Light-valve records.

steps louder than the composite and the latter 2 fader steps louder than the lightest print of the classical record. Signal-to-noise ratios are estimated as 24 db. for the toe,* 28 db. for the composite, and 29 db. for the classical. The permissible reduction in projected noise level is estimated to be 6 db. for the toe, 10 db. for the composite, and 14 db. for the classical.

In a theatre of 500,000 cu. ft., seating about 2000 persons, the level of loud dialog projection is about +20 db. electrical power delivered to the Western Electric loud speaker. In such a theater

* Actual measured range of experimental toe record between dialog and noise.

the audience noise is at a level of -15 db., while the noise due to theater equipment in the empty house is about -25 db.*

Fig. 14 exhibits the comparative levels of dialog projection and of film noise with and without maximum permissible noise reduction for the three types of record when the fader is set to give approximately the same projection level for dialog. In a theater of the size assumed, the composite type of record would usually be projected at step 10 on the fader. The amplifiers would then deliver about $+20$ db. to the loud speakers. If fader step 10 is acceptable for the composite record, the fader could be set at 8 for the toe record and would have to be raised to 12 for the classical print restricted to the straight line of the printer curve.

Fig. 14 indicates that 6 db. noise reduction, the maximum permissible on the toe record, would leave the ground noise louder than the audience noise when the dialog level is $+20$. Ten db. noise reduction in composite records reduces the ground noise to a level below the audience noise, whereas the classical type of record with 14 db. permissible noise reduction reduces the noise level almost to that of theater equipment.

Of these three records only the composite type represents sound processing nearly like that of the picture and thus is the only type of processing which is possible for newsreel records, where sound and picture negative are made on the same film. In this case the usual picture development of both negative and positive can be used, requiring for its success a proper choice of sound track negative exposure, of negative modulation, and of printer light, possibly also a suitable filter when printing the sound negative. The considerations which have been set forth in this paper will enable any one to determine the proper treatment of the sound record.

Conclusion

(1) The commercial types of variable density sound records on film have been analyzed and compared with the classical specifications for distortionless sound reproduction.

(2) Sensitometric data have been discussed and it is shown that the product of positive and negative sensitometer gammas derived from plots of visual diffuse density *vs.* log exposure is not equal to the over-all projected gamma of the sound track.

(3) The method of consulting the over-all characteristic has been described.

(4) The noise reduction applicable without distortion has been considered for each type of sound record.

(5) The projection levels of dialog and ground noise with the relative fader settings have been estimated with reference to an average theater.

In any sound film processing we have to consider the positive and negative development, the negative unmodulated exposure and percentage modulation, and the exposure of the unmodulated positive track. Fixing the positive and negative gammas leaves us free to

* These levels are referred to 0.006 watt as zero level. Audience noise and theater noise are stated in terms of their equivalent in power input to the loud speakers.

choose the negative exposure and the printer point. In the toe record there is found to be a considerable latitude in the location of the negative unmodulated exposure on the negative H & D curve. For all negative exposures within this latitude there is one optimum density for the positive print. Similarly in straight-line records of over-all gamma = 1.4, there is a wide latitude in choice of negative exposure, again with a definite positive density for a successful print. In each of the above cases there is a definite limitation on the percentage modulation of negative exposure: 45 per cent for the toe record where positive and negative gammas are each 2.0 by daylight time scale, 70 per cent for the composite straight-line record of negative gamma 0.50, positive gamma 2.1 by Cinex time scale. It is obvious that for composite straight-line records developed to other values of negative and positive gamma, there exist similar optimum combinations of negative exposure, negative modulation, and print density. It will be found that the combination suitable for the case considered in the text is also suitable for positive and negative gammas, each 5 per cent higher or lower than the particular values illustrated.

Increase in signal volume obtainable from the straight-line records, either composite or classical, is obtainable only by lowering the contrast to which the positive print is developed. Since this positive contrast is determined by the requirements of picture processing, louder variable density sound records must wait for a softer print development unless sound quality is sacrificed.

In Hollywood, in January, 1931, laboratory "X" used a sound negative developer giving a printing coefficient of 1.08. In this development the light-valve gamma of 0.47 was easily obtainable on Eastman positive film. At the same time laboratory "Y" used a positive bath and a combination of filter and lamp in the printer, which gave a true printer gamma of 1.58. The negative of laboratory "X" printed at laboratory "Y" would result in an over-all projected gamma of unity. The unmolested negative exposure could have been made 10 times the toe exposure, permitting 90 per cent modulation about this average. The printer points at laboratory "Y" could have been chosen for an unmodulated positive transmission of 0.25 visual diffuse. This would have meant a projected print transmission of 0.17, giving the same noise level as in the composite record described above, and a signal volume proportional to 0.30. The 90 per cent negative modulation would have been reproduced without distortion, the signal would have been 1 db. louder than in the composite record just mentioned, and 14 db. noise reduction could have been used without distortion.

The toe-record volume is not seriously affected by a slight variation in gamma, and it is about 2 fader steps higher than the composite straight-line record, over-all gamma = 1.4. At the same time the signal-to-noise ratio on the toe record is decidedly less than on the composite straight-line record, and is limited by the maximum noise reduction applicable without distortion. Wherever signal volume is the first consideration, the toe record is preferable. In the usual case, however, the most important consideration is the signal-to-

noise ratio. In this respect the advantage is decidedly with the straight-line recording.

Of the two straight-line types examined, the composite record more closely resembles the picture technic. The classical recording, over-all gamma = 1.0, is exceptionally suited to the processing of sound records which can be treated independently of the picture. In this case the same development can be used for the sound negative and the sound positive, resulting in an over-all projected gamma of unity with maximum signal volume of the sound print. When the sound negative is made on positive emulsion, toe recording is called for by light sources of restricted intensity, and has the advantage of saving the separate sound negative bath. Where a light source of sufficient intensity for straight-line recording is available, the advantages of the toe record are offset by the greater volume range between signal and noise which is obtainable on the straight line.

All things considered, the advantage lies with the straight-line record. Although lower in volume than the toe record, it has inherently a greater volume range for the same standard of quality, and this advantage is still further increased by applying noise-reduction methods.

In the discussion just concluded nothing has been said regarding the frequency characteristic for the reason that the high frequency cut-off for any record is determined by a number of circumstances independent of the processing technic; nor has anything been said regarding the practical problems of photographic chemistry and developer maintenance which must be dealt with in order to insure the most successful use of the photographic emulsion and, in the particular case of the toe record, the greatest stability in the shape of the H & D curve. It has been assumed that a uniform development was available for each type of processing, which means that adequate precautions were assumed to avoid variation in bromide concentration and in activity of the developing agent. It is commercially possible to maintain the developer composition by appropriate boosting, but the improvement in development formulas for both picture and sound record processes is a chemical problem of major importance with which the present paper does not deal.

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Whispering Willows

Frank Tanner

CINEMICROGRAPHY WITH THE 16 MM. CAMERA

*John C. Fardon **

THE MOTION picture camera has long been an essential instrument in the scientific laboratory for the recording of experiments and the analyses of objects in motion. Before the advent of the 16 mm. camera it was not always within the reach of the smaller laboratories and individual research workers to obtain the standard camera with its costly film maintenance. Furthermore a camera of the 35 mm. type had its disadvantages insofar as it was rather difficult to manipulate under the conditions of certain experiments on account of its size. The modern 16 mm. camera is ideal in the respect that it is light in weight, compact, flexible, and within reach of most investigators. In this laboratory the Bell and Howell 70-D camera is being used to good advantage in recording and following feeding experiments on animals, making records of instru-

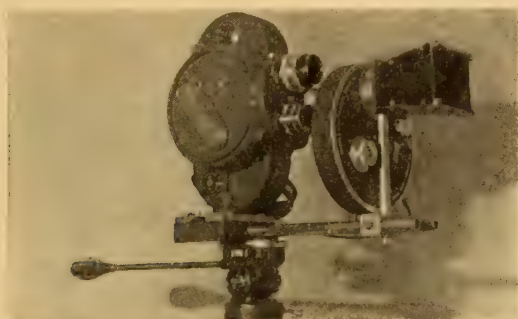


Fig. 1

ment set-ups, and the photography of microscopic objects. Fig. 1 shows the 70-D mounted with the Badgley automatic dissolve and the effect-box. The adjustable mounting and effect-box were constructed in the laboratory. By double exposure and with the aid of the effect-box, with the proper masks, it becomes but a simple matter to record a series of experiments such as the comparison of a set of animals subjected to abnormal conditions to a set of controls. The applicability of the camera is obviously numerous and too well known to give further mention here.

It is the purpose of this article to describe some minor modifications and developments made in cinemicrography in conjunction with investigations on the adaptation of protozoa to abnormal environments.

* Basic Research Laboratory University of Cincinnati

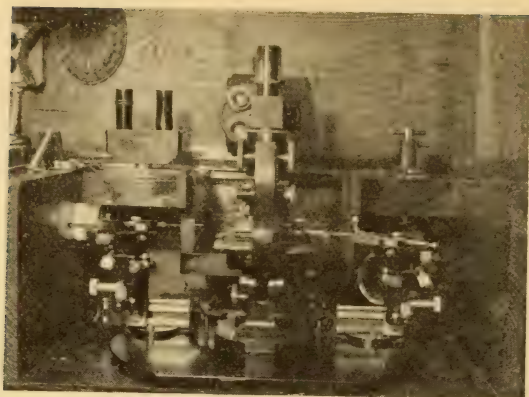
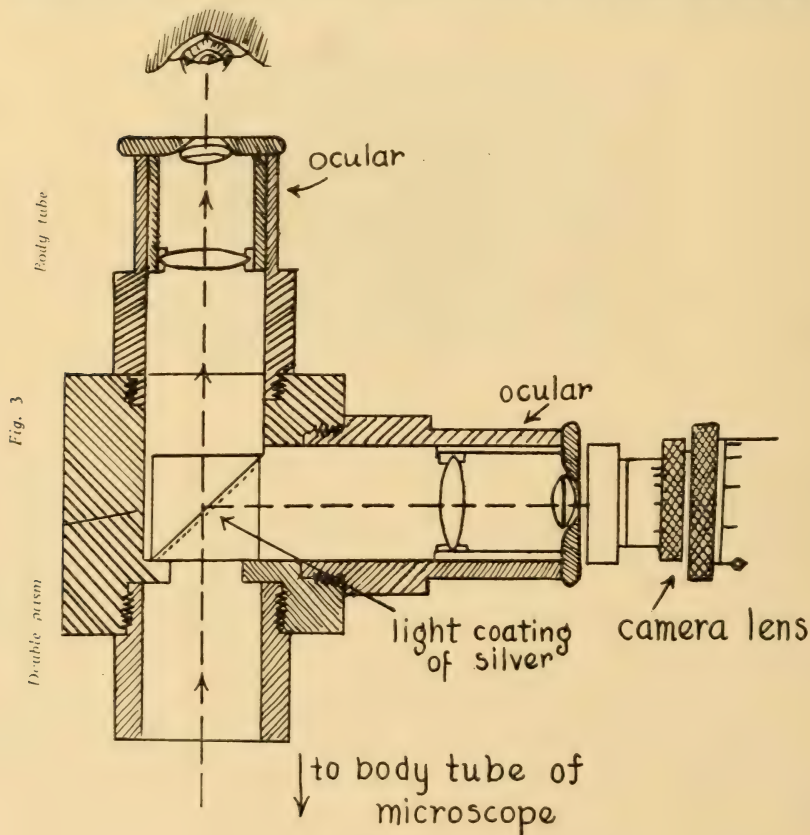
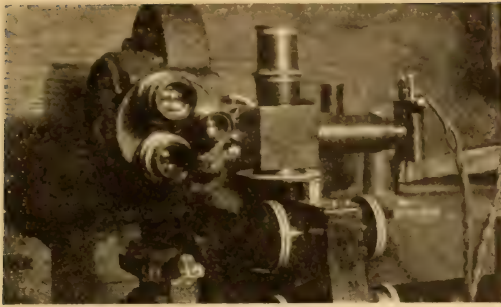


Fig. 2.

Fig. 2 shows the general set-up of microscope micromanipulator, and camera. A special body tube has been constructed to fit the tube of Bausch and Lomb CBE microscope. As shown in Fig. 3, the usual method is used to split the light in two directions with a double prism. One of the 45° prisms was coated with a thin film of silver



*Fig. 4*

and then cemented to the other with Canada balsam. As shown in the figure the prism is so mounted that the greater percentage of light received from the objective is reflected to the ocular facing the camera lens, the lesser amount to the eye. It has been found that very good exposure and definition can be obtained by leaving the lens in the camera since the rays of light upon emerging from the ocular are so nearly parallel that when the camera lens is set for infinity the object being observed with the eyes is also focused sharply on the

*Fig. 5*

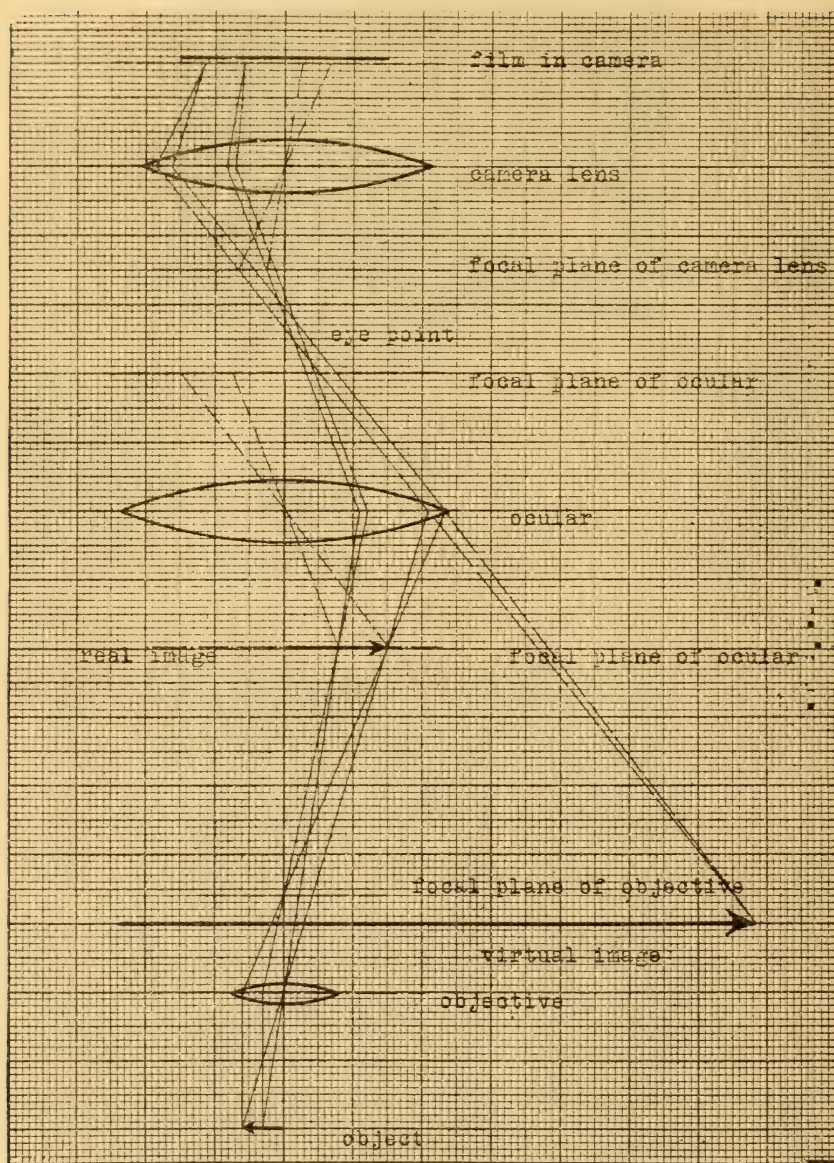
Path of Rays Through Microscope and Camera

Fig. 6

film emulsion. Fig. 6 shows a diagram of the path of the light rays through the microscope and camera lens. All pictures made thus far have been with the F-1:8 and F-1:5 one-inch lenses, the lens hood of the camera nearly touching the ocular of the microscope.

An ordinary automobile 50 c. p. lamp is used as a source of illumination with a condenser for collecting the light. Sufficient illumination can be obtained by this method when using oil immersion and a magnification of $1800\times$, the camera speed at 16 frames per second.

On some deeply stained slides it is necessary to bring the voltage a little over that at which the lamp is rated. But then with inanimate objects the camera can be operated at half speed.

For the determination of the correct exposure a thermopile is used (obviously the photoelectric cell or selenium cell will answer the same purpose). Fig. 4 shows the thermopile (in this case the Adam Hilger 10 junction thermopile used in their infra-red spectrometer) in its light-tight housing. When having the object on the slide properly centered under the objective, the ocular opposite the camera lens is removed and the thermopile inserted in its place. Readings are then taken with the galvanometer (which should have a sensitivity of about 1×10^{-7} amperes) and the illuminations so adjusted until the desired setting is obtained. It is naturally necessary to first calibrate the light sensitive cell by trial exposures and making a record of the galvanometer reading.

In Fig. 5 may be seen three microphotographs taken by the methods described above. Referring to the figure; a, is a shot from unstained encysted protozoa; b, a stained section of a portion of the grasshopper test is showing the deeply strained chromosomes; and c, living protozoa. A magnification of $860\times$ being used on all three preparations.



Lights

THE LARGER SCREEN

Dr. L. M. Dieterich, A.S.C.*

Introduction

THE motion picture industry is founded upon the business principle of renting to the public for cash, pleasurable reactions upon its ocular, and lately also upon its aural senses.

The monetary exchange value of this service, by the producer to the public, is preponderately controlled by its reaction upon the *sight* of the spectator, and the keystone of the physical aspects of such service is the picture.

For the purpose of this study the *pictorial* or artistic-aesthetical qualities only of the picture can be considered, because they are, as will be shown below, those which are of the greatest influence upon the financial reaction which determines the economical value of every motion picture production.

If these aesthetic qualities produce sense pleasure, then the spectator likes the picture and willingly pays for the opportunity of seeing it.

The greatest sensepleasure the human eye is capable of producing, is caused by viewing nature.

It is this form of sensepleasure which makes us call a thing "beautiful" or causes us to recognize the beauty which is inherent in nature.

The retinal impressions of the pictorial elements of nature enable man to judge by automatically developed standards, any other pictorial elements as to their influence upon the beauty concept. If they produce sensepleasure, man feels beauty by nerve reaction.

When looking at any manmade object the sensereaction becomes increasingly more pleasurable the nearer such object approaches by its pictorial characteristics the elements of beauty taught to man by nature itself.

These naturetaught elements register upon the ocular nerves through and by the physical equipment or structure of the human eye. We call the totality of phenomenae produced by its physical or optical characteristics—natural vision.

Natural vision observing nature pleurably, perceives, and by experience gradually recognizes, certain fundamentals of harmonious conditions in nature which become effective in their relativity to each other and the whole.

Conscious or subconscious recognition of such harmonies, pervading all nature, enable man to produce art, an endeavor to simulate by manmade harmonies the sensepleasures nature bestows upon us.

These endeavors found during the last few decades new means of physical expression in the creation of motion pictures.

By the very nature of their conception and the so far available technical means, motion pictures are limited to the showing, in rapid succession, of a number of still photographs of an object taken at certain time intervals and similarly projected upon a rectangular screen.

* Consulting Engineer.

The most incisive restriction to natural vision lies in this physical limitation of the motion picture by sharp, straight, unnatural lines: by the screen frame and its unnatural shape.

History and Evolution of Screen Shape and Size

The shape of the screen has throughout the existence of motion picture projection, simply been an enlargement of the film picture frame or a rectangle of the proportion of 3 to 4. Its size was and has until lately been fundamentally governed by the grain conditions of the film picture and also slightly modified by local theatre conditions, i. e., optical efficiency of projection machine, throw, screen surface characteristics, illumination, minimum screen distance, etc.. etc.

The selection of the present size of a film picture frame and its proportions was simply an arbitrary selection by Edison and Lumière, for economical and practical reasons. After both Edison and Lumière adapted the four-hole perforation, the present frame size became, through their absolute control of the early film market, a standard.

If, during the years of motion picture development, artistic minds suggested a reconsideration of frame proportions and film sizes, their efforts were, on account of the commercially and universally adapted standards, fruitless.

It was only lately, when the introduction of sound on film methods robbed the picture frame of a considerable part of its width, that a change of film and frame dimensions became imperative.

Technicians began to study the problem energetically, and the selection of a new standard was sought for. The correlated screen size became an important part of this problem.

Unfortunately the searching work of the technicians was only a study of statistics of the pictorial art. The rectangular limitations or the framing of a picture were accepted without discussion. The work of the old painting masters was searched and studied. The proper artistic proportions of rectangular framing were studied, going for support and study even as far back in history, as to consider architectural proportions of the "rectangular" in the classical art. Hellenic art was accepted as "the" art of the ages and there the research work started.

The excellent and exhaustive work of Loyd A. Jones, C. L. Gregory, W. B. Rayton, A. S. Howell, J. A. Dubray, F. Westerberg, etc., brought about the so far unrefuted result, that a 5x8 proportion of a picture frame rectangle conforms most closely to the rectangles appearing in the outstanding records of beauty in the known history of art.

The author has, however, failed to see or hear of any research, endeavoring to find the psychological background for the establishment of the 5x8 proportions by the "masters".

We have no statistics, no records dwelling on this point. If we, however, are justified in assuming that art depends upon the creation of "significant form" (see Clive Bell), we are also justified to assume, that significant form, as conceived by the creative mind of the artist

No.1
PERIMETRIC DIAGRAM
 BINOCULAR AND MONOCULAR
 FIELDS OF NATURAL VISION OF
 THE NORMAL HUMAN EYE

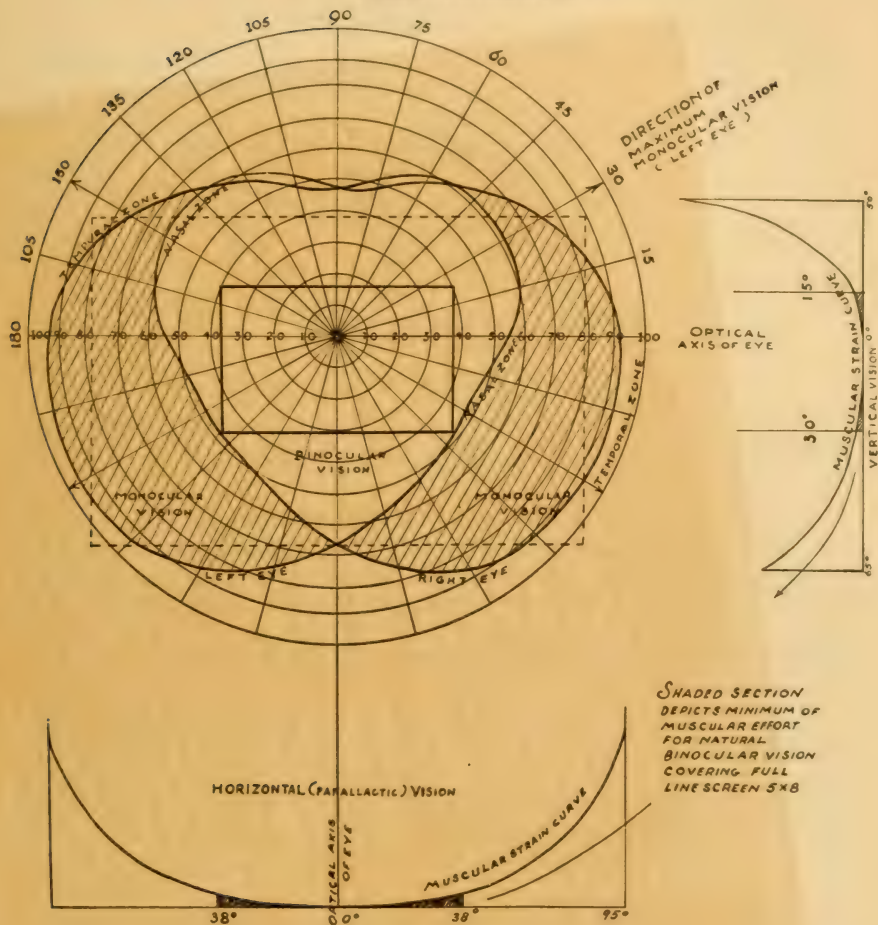


Fig. 1

and recorded by his skill in visual form—was originated by the impressions and nerve reactions of the artist's eyes, and that his work also, becomes of importance and value only by visual inspection.

To study screen sizes and proportions from the ground up, we are therefore forced to first study the optical characteristics and psychological reactions of the natural human vision.

It may be considered unfortunate that commercial eagerness selected lately, more or less arbitrarily, a few shapes and sizes, before art, science and engineering had the opportunity to harmoniously develop and recommend a new standard and that certain exponents of the industry so vigorously supported these secretly developed innovations with unlimited capital and most energetic technical and commercial activities, so that we are now facing a similar situation as that created by Edison and Lumière years ago.

To return to the human endowment which is the basis of all artistic conceptions, endeavors and work—natural vision.

Natural Vision

It is of elemental necessity to first thoroughly understand what natural vision is, its psychological characteristics and physical limitations.

It is a classical example of the evolution of the genus homo. There is a vast difference in the structure, efficiency and the nerve reactions, between the optical system of the different species of the animal kingdom. Let us consider for the purpose of this article with due apologies to the exponents of religious philosophy, and solely from the optical point of view, man as the mentally highest type and only truly upright specimen of the ape family.

There are even between the ape's and upright man's optical system differences, solely the results of evolutionary adaptation to the mode of man's normal physical behavior. The normal upright position of man evolved characteristics of his optical system, which are best described on hand of diagram 1. The normally upright posture of the head developed the normally horizontal position of the optical axes of his eyes.

Without going into the progressive results of evolution, (determining its details), the field of vision is shown for the right and left eye. The parallax or horizontal distance between the two eyes (about 70 mm.) has been disregarded in this diagram, because it disappears, as far as its effect upon the field of natural vision is concerned, if we consider only distant, converging vision; an assumption, justified for the scope of this article.

We observe that the field covered by the vision of both eyes, is approximately heart-shaped, with two lobes attached on each side, extending downwards and representing the vision of the single eyes only. The axes of the two eyes are both projected upon the center of the diagram.

The totality of vision, however, extends from this center more downwards than upwards, and a rectangle, closely following the outlines of vision totality, shows a dimensional proportion of very nearly 5x8 (see dotted rectangle).

This totality of natural vision, for a normal human eye, is of course only correct for a fixed position of the head.

Analyzing our viewing a screen picture, we can consider this condition only, as the movement of the eyeball is very much more rapid and of less effort, than that of the head.

There are, however, also within the range of eyeball motion, zones of comfort and discomfort, extending from consciously effortless ranging of the optical axis to its deflection by perceptible muscular effort or even painful strain. Considering the most important direction of meridian of vision, i. e., the parallactic or horizontal range of vision, we find that the extreme, covered by painful muscular exertion, covers in the average about 100 degrees on each side. This zone is, however, only relating to the respective single eye. The next zone covered in its extreme by perceptible muscular effort, embraces about 70 degrees on each side, whereas the consciously effortless range of vision of both eyes, covers theoretically about 38 degrees on each side.

In actual, every day natural vision, both eyes cover horizontally about 30 degrees on each side, or we have an effortless view of about 60 degrees in the horizontal meridian.

In the vertical meridian the effortless vision extends to about 15 degrees upwards and about 30 degrees downwards; this is a classical result of evolution of the human optical system—following the normal movements of upright man on the ground, with most attention necessary for obstacles or dangers, characteristic of the ground he walks upon.

The diagrammatic curves of muscular efforts for the deflection of the optical axis of the human eye from its normal position, looking "straight forward," shows the geometrically increasing energy, necessary to look "sideways, up or down" to the limits of vision. They also show the nearly effortless instantaneous covering power of the eyes for binocular vision, 15 degrees up, 30 degrees down, 38 degrees each side.

If we inscribe into these limits a rectangle, we find it most closely expressing a dimensional proportion of 5x8. It has been of singular interest to the author, to find that the results of his research work in natural vision, simply on a basis of analytical logic (abstract as far as screen proportions are concerned), coincide with the results of statistical research, so thoroughly conducted by others.

Rectangular Border Line

It may be of interest to consider here for a moment the reason, why pictures are usually contained within "rectangular" borders, when we know the actual peculiar curved border line of natural vision.

Our earliest records of primitive pictorial art show no border lines. We find borders only when architectural art was sufficiently developed to show beauty in "significant forms," characterizing the various epochs in architecture, be they Chinese, East Indian, Babylonian, Egyptian, Hellenic, Mayan or others. The hard material used for the edifices constructed under these different significant forms, forced upon the early artist the characteristic human deviation from nature—the straight line.

In the design of the earliest monuments, there naturally appeared surfaces, bordered in their simplest and most impressive contour, by straight lines, as rectangles.

If the predominant proportion of height and width in the most "beautiful" examples of early classical architecture of 5x8 was the result of the innate sense of beauty of the builder—if it was his endeavor to follow the effortless range of vision of his eyes—designing and correlating his system of beautiful proportions for a definite viewing distance—we do not and never will know.

Fact is, however, that these proportions were established in the progressive architectural arts, and that certain periods of Hindu, Egyptian and Hellenic art show a conscious recognition and use of only recently rediscovered laws of harmony or fundamental proportions of lines, surfaces and space elements pervading all nature.

Fact is also that there came a time, when such surfaces were embellished by a variety of designs in order to cover their plainness, a time, when pictorial art was called upon to beautify these surfaces.

Of our earliest records of pictorial art, mural paintings fall within this class.

It was not a question for the painter to design a fitting border for his composition. The question was to compose his picture for an already existing borderline. The aesthetic pleasure produced by viewing of such "beautiful" forms, associated the combination of paintings and rectangular borders for all times, as a necessary basis for all future artistic endeavors in pictorial art.

A rectangular border of 5x8, as an absolute "necessity" for finished beauty in a picture, is successfully contradicted, however, by the fact that we have a great many masterpieces, especially in movable paintings, which, although mostly rectangularly framed, by no means show the 5x8 frame proportions but follow the concept of composition, to whatever frame proportions the painter selected, governed either by his sense of beauty or by his cognizance of the rules of natural symmetry.

In motion picture practice there is an added handicap to our artistic endeavors: The art restricting rectangle becomes, once established, so far unchangeable, either in proportion or size and the director and cameraman have to exert more than normal artistic efforts, to always cover this unchangeable frame area with *beautiful* compositions.

In view of these today existing restricting conditions, it seems that a 5x8 motion picture frame should best cover artistic-aesthetic demands.

For the determination of proper screen areas, however, the limitations of effortless natural vision without head movement should be considered as of fundamental necessity.

Symmetry in Nature

The foregoing study of rectangular (screen) proportions shows an interesting harmony between the demands of natural vision and the characteristics of outstanding pictorial art as far as pleasing rectangle proportions are concerned.

These proportions become, however, truly authoritative, when we find that they are in close harmony with those proportions which absolutely govern all relativity of outline, surface and space values in living nature and which proportions nature taught us to consider as the fundamental elements of beauty.

This harmonious relativity, underlying beauty in nature in its innumerable and often evasibly subtle manifestations, is known to us under the collective name of symmetry. (Symmetry in its broad sense meaning analogy, analogous to nature.)

The simplest forms of nature's symmetry were recognized by early man and used in his art endeavors—similar efforts of imitation.

They form the basis of any design, either as evenly spaced line-forms around a central point or as evenly opposed lineforms on both sides of a straight line.

This part of harmonious relativity is easily traceable through the so called inanimate part of nature's products and is commonly called static symmetry.

The higher and so far recognized highest forms of such harmonious relativity are, however, found in what we call living nature.

Upon such highest forms of living symmetry nature built and brought forth the most inspiring crystallization of beauty—the human figure.

Less impressing, but of not less underlying beauty, the countless forms of animal life, such as our fauna and flora, growing crystals, etc., are all a living development of very elementary and simple proportions, in fact of one proportion, that one proportion, commonly known as the "golden mean" for which the beautiful name "a divine revelation" is of nearly awesome significance.

Modern philosophy of art calls this symmetry, *the dynamic symmetry*.

To thoroughly recognize, understand and assimilate its principles we should think in terms of surface or space relativity rather than in terms of Euclidian fundamentals, be they numerical, algebraic or geometrical.

To make these principles readily understandable the analytical studies of Hambidge, really their rediscoverer, have furnished us with partly numerical and partly geometrical explanations, which, easily understood, and applied, enable us to more clearly follow the precepts of nature as far as beauty is concerned.

The Rectangle of the Whirling Squares

It is of singular significance that the groping study of proper motion picture screen proportions should reveal to us a guiding sign through the analysis of natural vision and that even more important and compelling, the analytical study of nature's beauty laws should again bring us certain geometrical rectangle characteristics, which fully and clearly show us the path to the perfect rectangle, as far as nature's beauty standards prescribe.

(The author wants to emphasize at this point that all these analytical considerations are only apparently irrelevant to motion picture economics and that he hopes to prove by his conclusions below their important economic value.)

Comparative contemplation of significant forms in nature soon shows certain harmonious relative values characteristic of all such beauty forms.

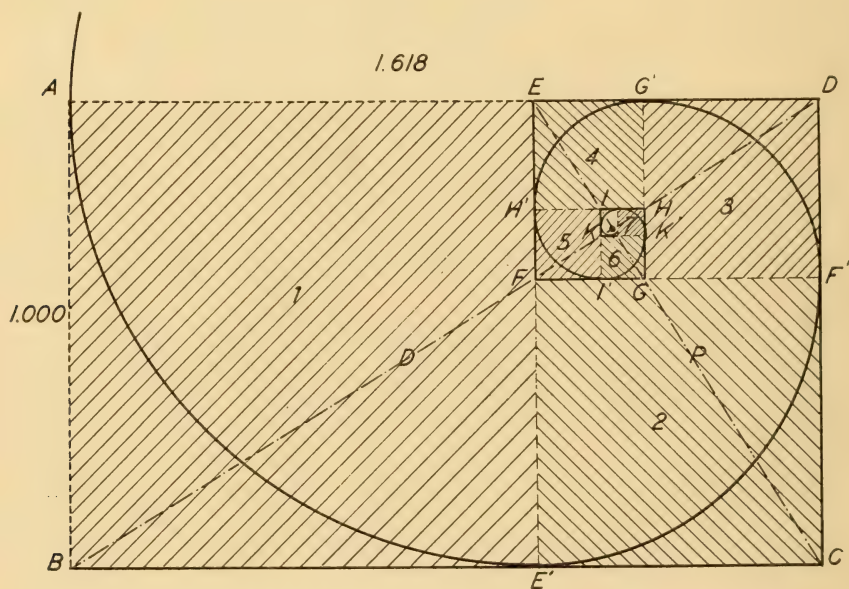


Fig. 2.

They were apparently, as far as we know, first recognized by the early Egyptians, found expression in their religious rituals, the priest controlled art endeavors, survey methods, etc. This knowledge transpired into Greece and developed into a more or less closely guarded philosophical system and art school which furnished us during the brief span of its applied existence with the most beautiful art examples of existence.

Our numerical system is too crude to furnish us an easy applicable yardstick for nature's beauty mysteries, and geometrical considerations have been found of a higher degree of applicability.

The previously mentioned "golden mean" is therefore shown in its simplest form on hand of diagram Fig. 2 which shows its application to a rectangle.

This diagram shows a rectangle in which not only the linear proportions, but also the area proportions in all their subdivisions maintain the most pleasing relativity of 1:1.681 (or approximately $5:8 = 1:1.6$) if developed from the "golden mean." Graphically Fig. 2 shows the simple means of producing the never ending variety of sizes, rectangular and curved patterns—IF—the start is made by a diagonal BD and its perpendicular CE, "the golden mean process."

Starting at B and turning at right angles at every intersection with these two lines produces a whirl of succeeding squares 1, 2, 3, 4, 5, 6, 7 and so forth ad infinitum, producing at the same time continuous reciprocal rectangles of 1:1.681 proportions CDEE₁—DEFF₁—EFGG₁—FGHH₁, etc. — curve bound sectors AEE₁—E₁FF₁—F₁GG₁—GHH₁, etc., all commensurable with each other and the whole. These curve boundaries are parts of a spiral, known in mathematics as the logarithmic spiral.

The whole Parthenon, the most beautiful edifice known to mankind, is from its floor plan to its last frieze detail or column curve built upon the details of relativity in line and area shown in Fig. 2. So are all the classic forms embodied in Greek vases of the brilliant period of Hellenic art; and an analysis of the human body and skeleton on hand of the apparent mysteries of this graphic study reveals dynamic symmetry in its most perfect application.

It must, however, be well understood that the in every respect "classical" rectangle of 1:1.681 is the geometrical and mathematical basis or fundamental expression of a system of proportions manifesting itself in all cosmic phenomena, perceived by man's senses and that a vast number of proportions can be built upon this fundamental once its characteristics are understood.

As an example: Dr. C. T. Hamaker, a profound student of nature's laws, and of the ancient philosophers, evolved a so far unpublished system establishing the relative value of certain chemicals for medicinal optimum value; this system has been in collaboration with the author checked by certain characteristics of the spectrum, especially as relating to the inter-relativity of the Francenhofer lines and finally found in exact harmony with the graphical and mathematical studies and results of the above stated "divine revelation".

Research in colloidal chemistry, in harmonious color values, in musical sequences, the easily traceable logarithmic spirals shown in the positional arrangement of trees, leaves and seeds in plant life, the study of the relative value of the radii of the electron orbits and the number of electrons in such orbits, the study of available records of astronomical observations of nebulae and star galaxies, and even the sex determination in biological problems—resting upon the relative number of X chromosomes to other chromosomes in the fertilized egg—all indicate definite relationship to the fundamental divine revelation. We are, however, hampered by the crudeness of units and unit.



Fig. 3

systems in the graphical and mathematical sciences and forced to train our minds to think in spatial units.

Einstein recognized nature's governing rules of relativity and although his nearly super-human intelligence no doubt clearly understands them, the comparatively crude yardstick of mathematics forced him to show proof of his thesis in such complex form that only few other humans can clearly follow his deductions.

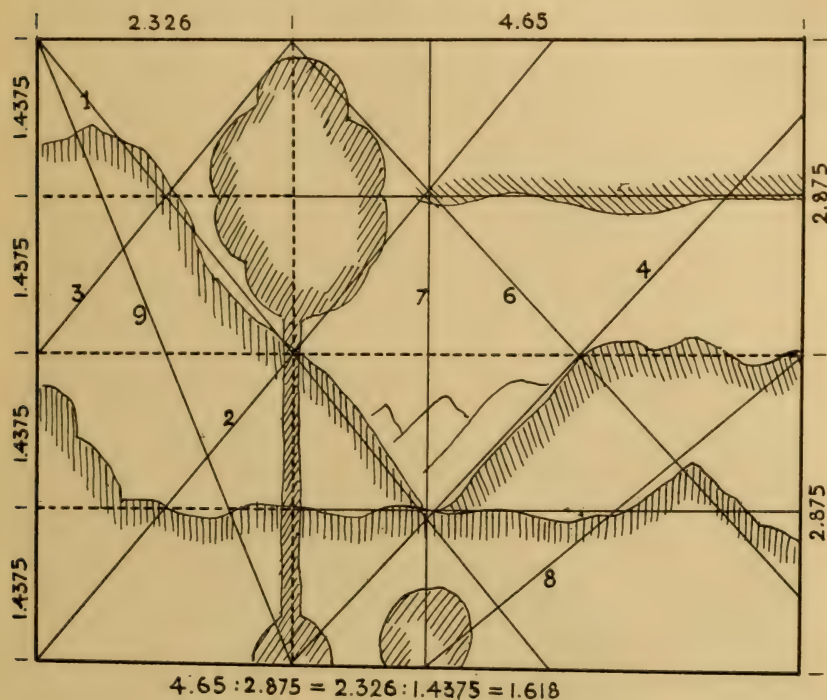


Fig. 4

Although the space limitations of this article force the author to show only flashes of similar phenomena in nature, he hopes to impress the reader with the fact that all sense-pleasure producing activities of man must or should be founded and governed by the beauty rules of nature.

This leads us back to the endeavors in the motion picture industry and still more restricted beauty in photography as established by composition and its bordering.

Fig. 3 shows a photograph accidentally picked up by the author with a recognition of its inherent beauty elements.

Fig. 4 shows the graphical analysis of the same on hand of the rules of the whirling square rectangle and

Fig. 5, its final bordering as determined by such analysis.

A visual comparison between Figs. 3 and 5 clearly shows the enhanced beauty of Fig. 5 and its closer approach to natural vision.

*Fig. 5*

The numbering of the lines in Fig. 4 shows the progressive graphical analysis as applied in this case.

It must be here recorded that the name "dynamic symmetry" has not been coined as a characteristic of moving but of living products of nature which truth is often misunderstood by the student primarily interested in motion picture technique.

This very condensed study of what we might call the aesthetic principles of nature went intentionally into the few realms of science where its research study seems to bring us nearer to the mysteries of life than any other research avenues so far trodden.

Its might and value reaches also that simple problem, screen proportions—simple but so far reaching in its determination for the future of the motion picture industry and its allied sciences and practices.

The author feels it his duty as a sincere student and well-wisher of this industry and its mighty influence upon the evolution of man to offer the results of his thoughts and study as an invitation for deliberation and earnest consideration.

Economic Aspects

Although at the time of this writing the problem of the "wider screen" has lost its, at the start, official importance, it is and must be faced in the near future.

Before sound entered into motion picture technique screen sizes and proportions were a standard. The inexorable demand upon film area made by sound destroyed these standard and changed them in a percentual majority of sound systems beyond acceptable limitations.

These changes influenced the desired balance between expenditure and income, showing an added red light to the producers. The technicians were sympathetically consulted, but suddenly other commercially economic problems faced the producers and they perforce assumed the position of the ostrich with his head in the sand.

This is not meant as a derogatory criticism of the producers' business acumen but simply as a statement of facts.

The author hopes that by the time this article appears in print other more acute and economically more important problems confronting the producer will be solved for his and the industry's benefit and that he shall accord his wholehearted support for the concerted efforts of scientists, technicians and showmen to find and establish a logical solution of the problem of the "larger screen."

The author believes he has besides others shown the path to follow.

If the foundation is right, the superstructure will stand. What proper developments will bring lies in the realm of speculation and dreams. Technicians will produce progressive results and it depends entirely upon the producer, as final arbiter, what benefits may accrue to him, by increasing the beauty of his screen presentations.

He will still be in the business of renting to the public for cash pleasurable sense reactions.



Atmosphere

PROCESS PHOTOGRAPHY

*Gordon A. Chambers**

MARKED advances have been made in recent years in the technique of process photography, particularly in the field of application of the so-called traveling matte. Many of these advances have come about as a result of the limitations placed upon the cinematographer by the addition to his medium of sound recording. It is the purpose of the author in presenting this paper to bring to the attention of those unfamiliar with process work a general survey of the methods in use rather than to attempt to give an intimate description of these methods in the form of a text.

Process photography has as its objective two sorts of effects, those which are recognized by the audience as a deception or illusion and those which, unrecognized as "trick" shots, are inserted in a picture to lend production value. These latter effects are obtained by means of process methods because mechanical or economic reasons make it impossible or impractical to secure them by ordinary photography.

While the results obtained by high speed and trick crank photography fall properly in the field of special effects, it is intended by the author to limit this discussion only to those forms of process work which employ mattes. Two forms of the latter are used. These are known as the still and traveling mattes.

The earliest and surely the simplest of still mattes is the so-called "split" matte which is used just in front of the focal plane in the camera to facilitate the making of multiple exposures. T. K. Peters¹ mentions a ninety-foot production available in 1902 entitled "The Inexhaustible Cab" in which "... thirty-two persons enter the carriage built to hold but four, but none are seen to get out." This sort of effect was extensively employed in the early days of photography especially to obtain ludicrous or comedy effects such as that mentioned above.

At the present time that form of still matte commonly referred to as a "glass" is very often employed. This form of photography is mentioned by Carl Louis Gregory² and by Dr. A. B. Hitchins³ who illustrates the method of use. This process is very versatile in its ability to introduce detail into the picture which did not exist in the actual set just so long as the action on the set does not overlap into that portion of the frame which is to be exposed to the "glass." While glass is often used as the medium on which the painting is made, many of the paintings so introduced into a motion picture are made on an opaque support. This is usually done where the painting is subsequently double exposed onto the film on that portion of the frame which was suitably masked in the camera. The latter method is finding more general use than is the method of

* West Coast Division, Motion Picture Film Department, Eastman Kodak Company.

painting on actual glass and shooting through this glass on the set. The preparation of the painting can be done after the set action is photographed without tying up the space or set for the length of time necessary to prepare a painting on glass. One expert worker in this field has found that the use of chalk in various shades from black to white gives greater ease in the preparation of the background as the final matching of tones at the point where the two exposures join on the frame is more easily done with chalk than with oil colors. Too, the quality of the image obtained is different than that from a brushed-on oil paint and it is felt by this particular worker that the resulting composite is more uniform in quality.

While a glass is in every sense a miniature even though confined to two dimensions, three dimensional miniatures in the form of models are often employed to great advantage. With these also, it is possible to employ either single or multiple exposure to obtain the composite negative. For some effects it is desirable to employ both "glasses" and models. Some very realistic effects have been secured for the screen by using model airplanes and dirigibles moving before the camera with one or more glasses interposed on which the clouds are painted. The resulting shot of a dirigible moving through beautiful cloud banks would be difficult to obtain by natural means without the expenditure of a great deal of time and money.

In the use of miniatures or models, it is extremely important that not only the perspective of space be maintained but also that which might be termed the "perspective of time." Attention has been called to the importance of this by several writers. Both J. A. Ball⁴ and G. F. Hutchins⁵ have discussed this subject from the theoretical standpoint and have stressed the relationship which must exist between time and linear magnification for a perfect illusion. Several interesting applications of the use of models to create special effects are described by Fred Waller.⁶

With increased development in the application of process photography has come the creation in the various studios of a "Special Effects Department," which devotes its time entirely to the creation of these illusions.

One of the most useful tools of the specialists who comprise these departments is the optical printer. Such an instrument has been described by C. L. Gregory⁷. Essentially it consists of a camera so mounted as to be able to copy one or more negatives moving in synchronism with the raw stock in the copying camera. One of the well known results to be obtained by the aid of the optical printer is the kaleidoscopic effect used to convey to the audience a train of thought in a character's mind. Such an example is cited in the paper by Waller, mentioned above. The optical printer is also used extensively for the routine production of duplicate negatives from master positives because of the fact that the duplicate image is an optical one rather than one secured from a contact printer. Greater sharpness is thus obtained. The motor-driven cameras of today may not be used easily for the making of fades and lap dissolves and it is

common practice to produce these on an optical printer. Mere fades are often made chemically, however, because of the ease and rapidity of this process.

Various applications have been found for the use of prisms and other reflecting surfaces in the production of effects. These may be used on the camera itself or subsequently in the making of a dupe on the optical printer. Sequences in which a ballet is dancing have been made to appear as though the dance were performed on a glass floor whereas the reflected image was obtained by the use of a prism or sheet of optical glass in front of the taking lens. In the optical printer several images from as many different negatives may be superimposed in a single composite by optical means involving the use of prisms for reflecting the respective images into the same plane.

It must not be imagined that these processes are only used singly as often two or more are used to obtain the desired effect. The major problems encountered in this work are accuracy in registration of the images and equal accuracy in the timing of the action of multiple exposures so that the events take place in their proper sequence without overlap. Figure I in the paper by Waller⁶ is a chart illustrating the intricate attention to detail necessary to the proper timing of the events in such a sequence of multiple exposures.

The developing of traveling matte processes to their present state of perfection has opened a large field to the producer. It might be mentioned at this time that a complete picture, "The Subway Express," made by the Columbia Pictures Corporation, was produced entirely by a traveling matte process. Two such processes are available at the present time. One of these, known as the Williams Process, has been described by its inventor, Frank Williams⁸. In this process the action is photographed against a black background. From the negative of this a duplicate negative is made which is intensified in order to produce a silhouette of the action. This silhouette is then used as a traveling matte in a projection printer during the printing of the background negative as it covers and leaves unexposed the space which is later to be used by the foreground action which is double exposed in from the original negative with a print from this negative as a matte. Several variations of this process are possible, either black or white backgrounds or colored ones in a connection with filters to secure contrast may be used. Inasmuch as it has been found that a spreading of the image occurs on the silhouette because of the full exposure given and the subsequent intensification and further because of the increase in graininess incidental to the multiplicity of duplicating processes employed, Mr. Williams has been engaged in a method of simplifying his process to overcome these difficulties. No information is publicly available at the present time as to the solution of these in the new process.

Another traveling matte process which has enjoyed a great deal of favor is that commonly known as the Dunning Process. This process is the result of efforts on the part of Carroll Dunning and Roy Pomeroy. The original Dunning Process has been described previously⁹. The procedure has been modified somewhat so that at

the present time the methods used by the Dunning Process Company and the special effects department of the Paramount-Publix organization are essentially identical.

From the background negative is made a positive transparency from which the silver is bleached and a yellow-orange dye substituted in its place. This transparency is run through the camera together with the panchromatic film on which the foreground action is being photographed against a blue backstop. The foreground action is illuminated by tungsten lamps screened with filters having a spectral transmission comparable to that of the dye in the transparency. The blue backdrop is illuminated by white light. This drop is painted with a special blue which is complementary to the yellow-orange dye used.

Suppose for the moment that no foreground is present. The running of the transparency through the camera in contact with the emulsion of the panchromatic film would result in an exposure solely to the blue light reflected by the backdrop. This exposure would be so regulated that the selective transmission of the dye in its various depths would result in exposing onto the panchromatic film a duplicate negative transparency.

Suppose now that the entire field of view of the camera is occupied by action. This portion would photograph through the transparency as though the latter did not exist by virtue of the color of the light in the foreground. The composite obtained is a combination of the two exposures, the background being a duplicate negative and the foreground an original exposed directly through the transparency.

Just as great care is taken in the making of shots involving the use of still mattes in order to have the shadows match, as these indicate the direction of lighting, so care is taken to simulate the actual lighting of the original background in the lighting of the foreground during the making of a transparency shot. The timing where the background is moving, such as in the case of a traveling shot showing a car moving along a road, is another item which necessitates great care. The perspective of the background and foreground must be the same and the depth of focus of lenses ordinarily used must be used in the making of the background in order that the composite will have the appearance of reality. The results which are possible with traveling matte processes are so diverse and amazing that the extreme care employed is at once worth the trouble and at the same time invisible to the audience.

There has been a revival recently in several of the special effects departments of one process for the making of shots of the traveling matte type which was employed nearly ten years ago. The advent of higher speed negative emulsions has made the process practical. The process referred to is the one in which the foreground action is performed in front of a translucent screen onto which the background is projected from a standard projector. It is possible by this method to obtain effects similar to those obtained by the use of a traveling matte, that is, the superposition of action onto a moving background.

At the present time a great deal of experimentation is going on as to the nature of the screen desirable, the type of projection print to be used as far as general density and contrast are concerned and other problems that have arisen in the course of actual trial of the process.

The variety of effects possible and the ability of the workers in this field to realize the possibilities of the various processes have contributed to the making of process photography a very useful and economical branch of the motion picture industry.

In conclusion, the writer wishes to acknowledge the courtesy and help from those many men in the industry who have contributed information to make this paper possible.

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"Action"

MOTION PICTURES IN NATURAL COLOR

W. V. D. Kelley*

A SUMMARY of the most pertinent subjects described in the 1930 issue of this publication follows, but for those interested in the subject the reader should consult that article by Hal Hall and William Stull, A.S.C., who say, "Color in motion pictures is apparently here and to stay".

Hall-Stull refer to the fact that Jenkins in 1895, and later Robert Paul, both made some of their earlier work in color by hand coloring.

Descriptions of the technical side are given of Kinemacolor, the Gaumont system, Kodachrome, Prizma, Multicolor and Technicolor.

The article ends with the thought, "without doubt the coming year will see remarkable strides in the color field".

As it has turned out there has not been seen any great improvements. This is written from the film capitol and there may be "great improvements" now shown or described elsewhere but, at this time, Technicolor is the only one equipped in this territory to fill the needs of producers. A recent exhibition of their film showed vast improvement in the quality.

Multicolor completed their new building and are rapidly getting experience with their films, for the plant is capable of large productions. Multicolor with their rainbow bi-pack negative are following the same method for color positives as described in the 1930 edition of the Annual.

The most interesting addition to the color-film colony is Consolidated Film Laboratories, Inc. They have adopted double sided film with the method of coloring similar to that used by Multicolor. Double sided prints are made by using the bi-pack (rainbow) negatives in two strips. Anyone making negatives in pairs by other than bi-pack means can have their prints made by Consolidated, who work for the trade. In the black and white film trade, Consolidated say they did make 90% of all films used by producers for distribution. Because of their alliance with the trade, it is logical for Consolidated to be prepared to fill the wants of users of color prints. The DuPack, made by DuPont, is available to any producer who can therefore make his color selection negatives while he can have his prints made, as he did formerly with black and white prints, by Consolidated. This method brings the producers back again to the control of the making of negatives by their own cameramen, with the dailies and releases made by Consolidated. The making of negatives by cameramen in the employ and under the thumb of the producers pleases the producers best.

Another producer who has made everything for his color productions is Mack Sennett. The DuPack negatives are utilized as in Multicolor and Consolidated. The prints are on double sided film. The coloring matter used on the positives is the same as already de-

* Chairman, Color Section, S. M. P. E.

scribed, but as Sennett has been going through a number of changes, the identical method used at this time may be fleeting.

Hall-Stull refer to the Keller-Dorian system of making color prints manufactured and sold by Eastman as Kodacolor (KODACHROME is the subtractive system, KODACOLOR is the additive system), and the possibilities for the professional field. This system depends upon lens formations formed in the celluloid base as in the Eastman 16 mm. Kodacolor. The emulsion is reversed and a positive made from the negative originally exposed on the film. This assures that the photographic record will always be in definite relation to the lens elements. It has, therefore, been difficult to make copies.

Famous-Players having had much experience with double sided emulsions and desiring, as Mr. Zukor has said, to add all the beauty possible to their films, make the stipulation that they must have single sided film in color. Famous-Players are planning for color and apparently deciding that the Keller-Dorian system most nearly answers their requirements, are spending time developing the "copy" idea for 35 mm. film. They have succeeded in producing copies, which have been shown to members of the New York section of the S.M.P.E. If this method works out commercially, which it shows signs of doing, and if the quality is good, Famous-Players may look forward to a bright future with color films. This method is used at present for three colors. It can be adapted to any desired number, such as two or four colors. The color formations can be in dots, lines or squares, depending on the formations of color used in the optical system. The film itself will have the celluloid engraved in lens formations, the emulsion normal and the distributed prints in black and white reduced silver on such a base.

Hall-Stull say under the heading of Kinemacolor "no one who ever saw them will be likely to forget the beautiful and spectacular scenes made by this process". "Kinemacolor's results were very beautiful—at best, quite equal to anything now current." What killed Kinemacolor in the United States? Lack of programme and the inability to keep the special projectors working. This would seem to require that whatever system is adopted should be available to any producer so that the theatres are assured of plenty of programme material, following the same means theatres followed in connection with sound. Had color at its birth done the same we would have nothing but color in films at this time. Improvements have already been made which shows it is feasible and possible to run films, made in this simple manner, without color filters, color bombardment or fringing. Such films offer no difficulties in making copies, as they are without any special engraved lenses and nothing special is required for the optical system.

Hall-Stull say under the Eastman's Kodachrome heading, "Clearly, to be truly a commercial success a process would have to be applicable, at least in projection, to all existing machines". Sound required a special machine (projector) but has not held back the introduction of sound. Color is not as revolutionary as sound but it does seem that any inexpensive change in the method of showing films, in all

color and sound would make it worthwhile to introduce such a means to the trade.

In connection with "Subtractive" prints—enabling them to be shipped in cans to all parts of the world—they do meet "Commercial" requirements, but are both expensive and difficult to produce.

"Tabu" is as much a silent film as Chaplin's "City Lights". Either film, to be used at its best, requires a sound machine. The films without sound can be shown in any part of the world, but both do require extra work to have them shown universally.

The same requirements, if met as regards the addition of color, can be made to show anywhere, with as little extra difficulty as the pictures mentioned in the preceding paragraph.

Cost of introducing sound has had no apparent effect upon its use in general, as the new costs are for machinery and not films. Cost of color added to prints neither needs to add to its cost nor slow up distribution. If the public want color then they will get it, and the additional cost of giving it to the public with the present costly prints will be forthcoming from the producers. This will be done by adding the present additional cost to producing. But if a means for making a satisfactory article without the present high cost is found, it is doubtful if any more black and white films will be seen.

Now that films become more real due to the addition of sound, it is logical and to be expected that color will add to realism and the public will have it.

Results, with economy, are a necessary requirement. Double sided raw stock has been reduced in cost. It is no longer necessary for producers to have special cameras. Film for negatives has been increased in speed—faster to light. Methods of coloring the films are open to any producer. Experience in coloring the prints is the only requirement for them to master and they are ready to proceed with the distribution of their sound pictures in colors. Plants for producing releasing quantities of color prints are available to the independents. We may, therefore, look for a more general use of color during the next year.



Aiming High

PRACTICAL EXPOSURE METERS UNDER PRESENT PHOTOGRAPHIC CONDITIONS

Hatto Tappenbeck, A.S.C.

UP TO date the professional cinematographer and photographer has given very little thought to the exposure meter. This is due to several reasons of which past experience is perhaps the principle one.

Every cameraman has built up his photographic knowledge without exception from practical problems and actual work behind the camera. The uniformity and reliability of the standard film in the past gave the experienced photographer a base from which to calculate his exposure. Constant handling of the material and the use of privately owned cameras, the lenses of which were intimately known to the cameraman, made his judgment of exposure practically fool-proof in all cases.

During the past year conditions in the motion picture industry have materially changed. On rare occasions we find a cinematographer still using his own camera. He has to take what the studio will give him. Arc lights have made way to incandescent to a large degree while in some both kinds of lighting equipment are still in use. But above all the film emulsions have been improved so rapidly that he did not have time to get acquainted with one, when already another, faster one succeeded it.

The change from orthochromatic film to panchromatic was slow, and gradually the pan type two supplanted that. Then, suddenly, the new fast film arrived; three times as fast. It took the motion picture industry by storm, but the storm was still blowing, when the new pan type two supersensitive grayback, antihalo film appeared. Still speedier than its predecessor!

Twice in a short time the photographic end of the industry was shaken up. Developers changed to an unheard of long time, lights were reduced to a minimum, lenses stopped down to stops, only used previously in bright sunlight. On exteriors, in turn, neutral density and other filters cut the light almost in half, before it reached the film.

And experiments and inventions are still in progress, in fact, seem to have only just started. At the same time the trend of films seems to lean towards pictures away from the home base in foreign countries and atmosphere, where light conditions are so different as to even fool the most experienced photographer at times. These are the new conditions and the environment to which the present cinematographer has to adapt himself.

In the past we used to confirm our photographic judgment by a short hand-test, a very reliable method, if carefully employed. But at the present where the saving of overhead and time on productions is of the most vital importance, we cannot hold up a company half an hour for a test. That is the time now required; the five minute soup of the past has been replaced by a development of twelve, fifteen, and even twenty minutes in the modern machines.

A much shorter and equally accurate way of determining the correct exposure as through a hand-test has been given us in the scientific exposure meter, of which there is quite a number of excellent types on the market. They work independently of time, temperature, and location. Although their methods of arriving at the required results vary considerably, they all depend for accuracy on the practice, good manipulation, and judgment of the individual operator. The practical outcome of the exposure will be as closely correct as those data obtained in engineering by means of a sliderule.

There are several photometers of merit on the market to suit the needs and requirements of every cameraman or photographer.



B & H Photometer

The B&H photometers, manufactured by the Bell & Howell Co. of Chicago, employ the simple principle of comparing a lighted filament of definite adjustment with the object to be photographed. The whole picture is clearly visible at all times. The three different types for use with professional motion picture cameras, Filmos, and still cameras vary only in the markings of the scales, which are most readily adapted to the purpose intended.

Based on an entirely different principle are the exposure meters which the Drem Products Corporation of New York puts out. Their nature is of the extinction type, i. e., the light reflected from the object is used to illuminate a figure on the ground-glass inside the meter. This figure may be gradually dimmed by closing an iris built into the instrument. When it disappears the correct exposure may be read. Only the Dremo, the photometer designed mainly for amateur use, gives a direct view of the object; the other types are simply aimed at the subject to be measured for light intensity.

Another useful precision exposure meter with direct view is the Bewi, distributed by the Burleigh Brooks Co. of New York. It shows the scene in monotone, surrounded by a scale of numbers which decline in density from 1 to 17. The highest number visible

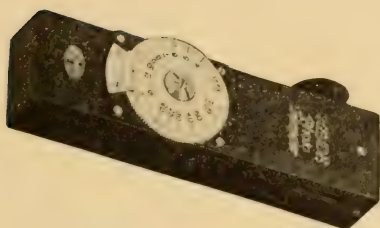
when the meter is directed towards the object, forms the base of the exposure readings marked on the barrel of the Bewi. This photometer is principally constructed for stillwork, while the Willo, the latest exposure meter on the market, is scaled for motion picture work. It is made in Germany for the Willoughby Co. of New York and is quite simple to operate. It may be compared in principle with the



The Dremophot Exposure Meter



The Cinophot Exposure Meter



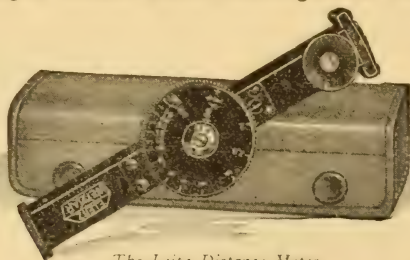
The Heyde Range Finder

Bewi. Only the scale surrounding the subject, which is also viewed on a monotone screen, gives a direct reading of the camera stop for orthochromatic film at a speed of 16 exposures per second. The different speed-, filter-, and emulsion-factors are readily determined from the movable scales on the barrel of the meter.

Any of the above pocket photometers are useful to the cameraman, whether they are graduated for cinematography or still-photography. The cinematographer is mainly interested in the one correct, basic exposure of $1/48$ second ($= 170^\circ$ shutter at a speed of 24 frames per second), from which he deviates in speed, shutter opening or lens

stop, and sometimes even in camera speed to satisfy his personal conception of that particular scene and character, or to create a certain desired effect.

In the above mentioned precision instruments the human eye plays a part in comparing the unknown light quantity with a known standard. Recently the sound technique of the film has developed the very reliable photocell. In the light-measuring device below this selenium cell has successfully eliminated the human element in judging exposures. Supplied with a known current from a small battery it changes readings on a galvanometer, to which the cell is connected, according to the light reflected upon it from the object at which the cell is pointed. Such an instrument is a built-in feature of the Moreno-Snyder continuous camera, a Hollywood product, where it measures directly the light which enters through the lens to be used for the scene.



The Leitz Distance Meter

A similar instrument in portable form has also proven its worth in the determination of the correct exposure in color work, in measuring the luminosity of motion picture projection screens in theatres, in giving the exact light value on motion picture sets, and in judging accurately the printing densities of picture and sound-track negatives in the laboratory. This type of photometer is based upon a very good scientific principle. The main objection towards its use is, that it is not compact enough; it takes up about the space of a small graflex. Until it has been reduced to pocket size it is not likely to become more than a laboratory instrument, required for very exact scientific investigations and measurements.

Those cameramen using one or the other of the above described photometers as a guide for their exposures have obtained very dependable results. However, a little practice is essential for fast and accurate manipulation. It is worthwhile to invest in a reliable exposure meter which gives the insurance of perfect timing under any light conditions, artificial or daylight.

This is of great importance in the modern picture which calls for interiors, sea-scenes, airshots, desert location, rugged timberland, etc. Quite often the various parts of the picture are shot simultaneously by two or three different cameramen, who are not acquainted with each other's method of lighting and photographing. The use of exposure meters in addition to a mutual understanding will render the photography of the film more uniform. Thus, it saves retakes and expenses, and does away with a lot of uncertainty and suspense on the part of the cameraman.

GRAININESS OF PHOTOGRAPHIC DEPOSITS—A REVIEW

*D. R. White**

THE problem of graininess of developed photographic deposits is particularly important to the motion picture industry as in motion pictures the photographic images are observed normally under such magnification as to make the structure of the image an important consideration. The non-uniformity of deposit which is designated by the word graininess may be considered as having three phases, which were pointed out by Jones and Deisch¹ in 1920.

- (a) Graininess due to the existence of individual particles of silver.
- (b) Graininess due to the clumping of the particles.
- (c) Graininess due to the agglomeration of the clumps.

The work done prior to this publication comes chiefly under (a) above, but since then the work has been extended to cover (b) and (c) also. The division thus made has been generally accepted as clarifying the problem though the divisions are not clear cut and sharp. Of these three phases (b) and (c) are of more immediate importance to the motion picture industry than (a) since it is true with present commercial emulsions that the individual grains are of such size as not to appear individually under normal conditions, while clumps and aggregates of clumps represent structural elements large enough to be visible all too frequently. However, phase (a) represents the limit that can possibly be attained with photographic emulsions of the present type and should be studied by the manufacturers and research workers to provide as far as possible for further general reduction in graininess. Much study has also been devoted to the individual grains as a means of formulating or checking theories or views of photographic action. For all of these reasons, therefore, much appears in the literature bearing on this point. The portion of this extended literature considered here will be limited to the part dealing with the relation of the developed silver grain to the undeveloped grain originally occurring in the emulsion.

In a paper written in 1904, A. and L. Lumière and A. Seyewetz² commented: "Following many works on the subject it has up to the present been generally admitted that the size of the grain of reduced silver in gelatine-bromide plates is uniform whatever be the developer used". They also noted that Abney had already found the size of grain of reduced silver in an overexposed plate to be finer than in the case of normal exposure and also that additions of alkaline

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bromide apparently increased the size of grain. Their own work, covering some fifteen developing agents or mixtures of agents, led them to agree in general with the earlier workers, noting, however, in addition that excess of alkali tended to produce a slight enlargement of the grain and that two developing agents, paraphenylene diamine and orthoamidophenol, produced much finer grains than other reducers. Further work of similar nature was planned and published later¹⁴. Wallace³ writing about the same time considered that prolonged development increased grain size and, therefore, recommended an active developer compounded to give the contrast desired in relatively short time. Scheffer⁴ presented photo-micrographs of undeveloped, partially developed and fully developed grains. The pictures show development with filament formation and give much evidence of clumping and irregular grain shapes. Hodgson⁵ showed results not corresponding to those of Scheffer as, under his conditions, the grains maintained the same shape as that of the original silver bromide, with the exception of such changes as could be ascribed to strains in the gelatine. Later, Davidson¹⁰ suggested that Scheffer's results were probably due to too high an intensity of light in making the photographs but found more changes in shape than Hodgson. Svedberg⁶ found that the size of the developed grain depended upon the original size of the silver bromide particle and the amount of development but not on the exposure. Higson⁷ stated that the grains resulting from development had closely four times the area that they had when undeveloped. Wightman and Sheppard⁸ proceeded to show that this conclusion was contrary to previous work of Higson and others. Mees⁹ considered that the evidence indicated the area of the developed silver grain to be substantially the same as the parent halide grain. Davidson^{10, 11} found in general an increase of grain size on development, the size increase being proportional to the photographic speed of the plate for a group of related emulsions of different speeds. Further statistical study indicated that the size increase depended upon both the emulsion and the developer, being in general greater for the faster emulsions. The nature of the grain deposited appeared different to him in the different developers, slow working developers of the borax type giving a notably spongy grain. Sheppard and Trivelli¹² did not feel that the proportionality of size increase and speed could be as exact as Davidson indicated, but gave data of their own showing a size increase greater, in general, for the larger grains. Wightman, Trivelli and Sheppard¹³ in their extended study of the size frequency distribution of grains in photographic emulsions noted increases of grain size for the larger grains, changes of relative positions of grains in the emulsion during development, and the reduction in size and total disappearance of some of the smaller grains.

As has already been indicated, much effort has been spent in attempting to find developing conditions yielding grains of minimum size. A. and L. Lumiere and A. Seyewetz² noted their intention of further study of developing conditions. As a result of their studies they recommended¹⁴ slow development with paraphenylene diamine as the best for fine grain and considered that the borax formula

recommended by the Eastman Laboratories showed only slight advantage over regular metol-hydroquinone developers with carbonate in them. Considerable discussion has centered in this type of developer formula as a fine grain developer. Bullock¹⁵ stated that the only value of this type of developer in grain reduction was due to its low alkalinity. A developer with the same alkalinity obtained from carbonate would show the same fine grain properties, Namias¹⁶ preferred a different slow acting formula with enough sulphite to obtain the fine grain advantage of the borax developer. Klugh¹⁷ found no advantage in this kind of developer over the usual metol-hydroquinone carbonate formulas. Lüppo-Cramer¹⁸ did not find reduced graininess with all emulsions developed in the borax developer. Viterbi and Barbato¹⁹ found reduction in grain size with high speed emulsions but not with lower speed ones. Veldman²⁰ observed that developer containing no alkali but sulphite gave as fine grain images as did the borax formula. He concluded that the sulphite largely determined the grain. Nauck²¹ decided that the size of the developed grain depended largely on the emulsion and could not be altered much by development variations. A. and L. Lumiere and A. Seyewetz¹⁴ also considered that the chief determining factor in all cases was the original size of grain before development which could not be decreased.

The evidence cited, strongly indicates that when silver bromide grains are developed under such conditions as to be separately observed, the original size of the grain is more important in determining the size of the developed grain than is the concentration, duration, temperature or formula of development.

Though this is the case, there is overwhelming evidence that in normal photographic deposits in commercial (multi-grain-layer) plates and films, there is a structure having dimensions much in excess of the individual grains. It is this larger structure that appears as the graininess designated by (b) and (c) above, the graininess due to clumping of grains and agglomeration of clumps.

Scheffer⁴ showed photo-micrographs of undeveloped and developed grains which in many cases show an apparent joining of the grains to produce larger aggregates. The formation of these aggregates may well be attributed to the developing action, as the filament formation shown would tend to cause neighboring grains to lose their identity. Wightman, Trivelli and Sheppard¹³ found cases in which grains originally close together separated and other cases where grains originally separated came closer during development.

There has been much discussion concerning the possibility of transfer of developability from one grain affected by light to another not so affected.

Svedberg²² did not find such transmission of developability but Trivelli and Righter²³ found great evidence of it. Toy²⁴ did not feel that the experimental evidence was sufficient to support the view that this transmission of developability had taken place. Trivelli²⁵ maintained that in certain cases such clumping had occurred in particular with high speed emulsions. Wightman²⁶ found no transfer of de-

velopability except when there was contact between the grains. Davidson¹⁰ found grains in certain emulsions tending to develop in pairs or large clumps. This effect was particularly noticeable in high speed emulsions.

The effects just cited may or may not be sufficient to account for all of the grain clumping observed as graininess of photographic deposits. In any case much practical benefit can be derived from observations leading to a way of minimizing or avoiding graininess even if the causes are not all immediately apparent.

Callier²⁷ had used the relation between diffuse and specular densities as an indication of grain size but this had not been found to serve as a measure of graininess. With these facts in mind Jones and Deisch¹ started out to measure graininess resulting from exposure and development of different products with varied conditions. They chose as their measurement of graininess the distance at which a magnified image of the deposit has to be viewed to appear uniform instead of appearing structured, i.e., grainy. Suitable checks and methods of standardization were introduced to make the measure finally obtained the same for different observers. These same methods were used again by Hardy and Jones²⁸ for further study of motion picture negative and positive emulsions. Crabtree²⁹ preferred to judge graininess by comparing prints on positive film processed to equal densities and projected in quick time succession, using experienced observers to judge relative graininess in the test. Landau³⁰ devised a comparator for comparison of the specimen with a series of photographic enlargements of grainy deposits. Conklin³¹ arranged a comparison microscope in such manner as to permit the relative magnification of the two fields to be changed at will and thus allow the relative graininess of an arbitrary standard and a sample to be compared by observing the relative magnification for equal appearance of graininess. Since all of these recent methods are based only upon some form of comparison of samples among themselves or with an arbitrary standard, a qualitative agreement is the most that can be expected.

Jones and Deisch¹ found the graininess of the deposits depending, in general, upon the density of the deposit, the developer used, the gamma to which development was carried and upon the original emulsion tested. The largest effect with a chosen emulsion was the increase of graininess with density, though in some cases, notably with paraphenylene diamine, the graininess reaches a maximum and then decreases. This particular developer has been noted for its fine grain and reduced graininess, but is hardly to be considered commercial because of excessive exposures and development required with it. Amongst developers of such characteristics as to be considered commercially, considerable differences were noted in the graininess of the deposits produced, a pyro formula appearing, perhaps, slightly the best of those tested. Fast emulsions were found to have greater graininess than slow, as would be expected from the experimental fact that they have as a class the larger original silver-bromide grains. The concentration of bromide in the developer, the temperature of

development, and the conditions of acidity and hardening action of the hypo were not found to have an appreciable effect on graininess.

Hardy and Jones²⁸ studied the graininess of the positive print resulting from negatives exposed and processed differently. For all cases presented the graininess of the prints increased with density to a maximum in the region of density 0.4 to 0.7 and then decreased with further density increase. They summarized their results in the following words:

1. It has been found that the negative exposure in the taking camera has considerable influence on the graininess of the resulting positive print. The minimum graininess is obtained by a minimum exposure. The graininess increases continuously with increase in exposure.
2. The time of development of the negative has practically no effect on the graininess of the resulting print when the development of the print is adjusted to compensate for the differences in the contrast of the negatives.
3. The use of diluted developing solutions to develop the negative produces a slight increase in the graininess of the print. This effect can usually be ignored in practice.
4. The graininess of the print was found to be almost independent of the developing agent used to develop the negative. Practically all of the common materials such as pyro, metol-hydroquinone in various combinations, amidol, etc., were tried and only negligibly small differences found between them.
5. Contrary to the claims that are often made, the fixing, washing and drying conditions were found to have no effect on graininess. The photographic materials were subjected to very severe conditions of warm solutions and slow drying in warm moist air but no increase in graininess could be measured.
6. The effect of the light used in printing on the graininess of the print was investigated. Printing by ultra-violet light was found to decrease the graininess. The graininess was found to be less when a diffuse beam of light was used in place of the usual parallel or specular beam. Practical considerations, however, make it undesirable to attempt to decrease graininess by this means.
7. The graininess of the print was found to be practically independent of the concentration or the nature of the developing agent.

8. An explanation is offered for the excessive graininess which sometimes occurs with certain types of subjects. This is probably due to the nature of the subject which requires rendering large unbroken areas by positive densities which lie near the maximum graininess. The various remedies for this condition are discussed.

Crabtree²⁰ attempted to parallel very closely practical motion picture conditions in his work and found little effect of exposure on graininess under such conditions. He found that matched prints from exposures at *f* 11 and *f* 3.5 on the same scene showed no appreciable difference in graininess. He found maximum graininess of the print dependent somewhat on the degree of development of the negative and recommended avoiding high gammas in development of negatives. In particular he recommended a borax developer as resulting in less graininess than other commercial developers. A. von Barsy³² spoke very highly of this borax formula for avoiding graininess in negatives.

The value of this type of developer appears to be in its slow developing action coupled with the solvent action of the sulphite upon silver bromide which permits the surface of the grain to be dissolved slightly thereby reducing the probability of development as clumps. If this is correct, other developing formulae, already cited, proposed to reduce the individual grain size, should be directly applicable to the reduction of graininess of negatives. Steigmann³³ suggested a pyro soda formula for avoidance of graininess. This is in accord with some of the earlier work showing that pyro soda developers produced somewhat less grain and graininess than others. Moyse and White³⁴ suggested a somewhat different borax formula as being suitable for fine grain negative development. Carlton and Crabtree³⁵ discussed the effect of variation of the constituents in a borax developer on the graininess producing properties of that developer.

It appears that pictures with a minimum appearance of graininess should be produced by—

- (a) Use of a negative emulsion having a fine original silver halide grain.
- (b) Use of adequate exposure but avoidance of over-exposure.
- (c) Use of a developer designed to develop the film with a minimum of graininess such as a borax developer of the type indicated.

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Camera Angles

ACOUSTIC POWER LEVELS IN SOUND PICTURE REPRODUCTION

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THE advent of sound pictures made especially prominent the question of acoustic power necessary to produce satisfactory hearing in auditoriums. The large scale employment of electrical sound reproducing apparatus made imperative a detailed investigation into this problem which had attracted some attention in the past. At the same time the perfection of electrical devices for recording, amplifying, and reproducing sounds gave us a degree of control over sounds which allows such fundamental measurements as those reported in Dr. Fletcher's book, "Speech and Hearing." Thus the question of acoustic power is most urgently raised when the means for regulating and measuring it had reached an advanced state of development.

It is the purpose of this paper, which is an amplification with some modification of a previous paper by the authors,¹ to consider the power levels dealt with in sound picture reproduction, with reference to the ear, the auditorium, and the electrical system. We undertake a consideration of what constitute desirable loudness levels in auditoriums, a study of the bearing of auditorium acoustics on the maintenance of adequate sound levels, and a determination of the power output of the reproducing equipment. Equations and curves relating required acoustic power and theatre volume are derived. Experimental data appear to substantiate our theoretical conclusions. We have attempted to follow the terminology developed in "Speech and Hearing."

Listening Levels

The optimum sensation levels for listening to speech and music will be first discussed. Ordinary conversation is maintained at a level of about 70 decibels above threshold of audibility for the strongest speech sounds, with about 50 decibels, more or less, for the consonants.² In other words, vowel sounds thus spoken are ten million times as powerful as when just audible. The so-called mean power fluctuates about an average closer to a level of 65 decibels. This intensity is such that words are heard at maximum intelligibility, greater or less intensity both tending to induce intelligibility. Accordingly, in the theatre this customary level may be considered comfortable from the standpoint of articulation and naturalness. Our observations in practice check this conclusion.

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¹Wolf, S. K. and Sette, W. J.: "Factors Governing Power Capacity of Sound Reproducing Equipment in Theatres," *Journal Society Motion Picture Engineers*, 15 (1930), No. 4, p. 415.

²Fletcher, H.: "Speech and Hearing," 1st Ed., D. Van Nostrand, New York (1929), p. 272.

Other phenomena must be considered. Noises due to external sources, audience, and ventilating and projecting equipment, ranging from 20 to 40 decibels above threshold according to our measurements, are usually present in an auditorium, sometimes necessitating an increase in loudness for good articulation. Coughing or nearby conversation occasionally raise the noise level above these figures. It has been found that ordinary speech is readily understood in the presence of what may be termed a usual amount of room noise.³ Everyday experience bears this out. The intelligibility of individual consonant sounds whose intensities are comparatively low will be reduced but with continuous conversation there is slight interference. Hence, as a rule, the level of reproduction in the theatre should be satisfactory when speech is heard at its usual levels. Such operation should have the advantages of being more restful than operation at unnaturally high intensities, besides being conducive to greater attention. In general we may neglect theatre noise as a factor in our problem, remembering that it is undesirable always and bothersome on occasion.

In the case of music with its complexity of sounds there is not available such a complete analysis as has been made for English speech. The acoustic power flow at threshold for speech is of the order of 4×10^{-10} microwatts per square centimeter. This figure was obtained from the phonetic power, that is, maximum value of power averaged over an interval of one one-hundredth of a second for a given sound, of 40 microwatts measured by Sacia and Beck for the loudest vowel sounds when spoken in an ordinary manner.⁴ It compares with the same value for the threshold of the pure tone at which the ear is most sensitive. Because of this it may seem that our selection is too low, but there seems no reason why the ear should not behave differently for complex sounds near threshold than it does for single frequencies. Accepting this value we then select an engineering limit of 80 decibels above it as the maximum mean power flow to be provided in theatres by electrical sound reproducing equipment. Such a selection should allow for variation in different types of speech as well as music. Our measurements on symphony orchestras in large theatres indicate that this figure is seldom exceeded. With speech the instantaneous peak powers may be 13 decibels above this as we shall see later. The conditions of noise and maximum power discussed here therefore limit the intensity range worked with to about 50 decibels.

The maximum flux of acoustic power is thus 4×10^{-2} microwatts per square centimeter. Fig. 1 shows what this means in terms of sensation and loudness levels for single frequencies.⁵ The falling off at low frequencies is very marked in the case of the sensation curve. The loudness curve is apparently the really important one since pre-

³Steinberg, J. C.: "Effects of Distortion upon the Recognition of Speech Sounds," *Journal Acoustical Society America*, 1 (1929), No. 1, p. 121. Also Fletcher "Speech and Hearing," p. 266.

⁴Sacia, C. F.: "Speech Power and Energy," *Bell System Technical Journal*, 4 (1925), No. 4, p. 627. Sacia, C. F. and Beck, C. J.: "The Power of Fundamental Speech Sounds," *Bell System Technical Journal*, 5 (1926), No. 3, p. 463.

⁵Fletcher: "Speech and Hearing," p. 230.

sumably a loudness balance throughout the audible range is desirable. Evidently in any instance in the chain from studio to theatre where there is a limit to the power possible to handle, the low notes will probably be the first to give trouble as they require greater power for equal loudness. However, it must be kept in mind that the presence of many partial tones in most signals make impossible the application of these curves to do more than to indicate tendencies.

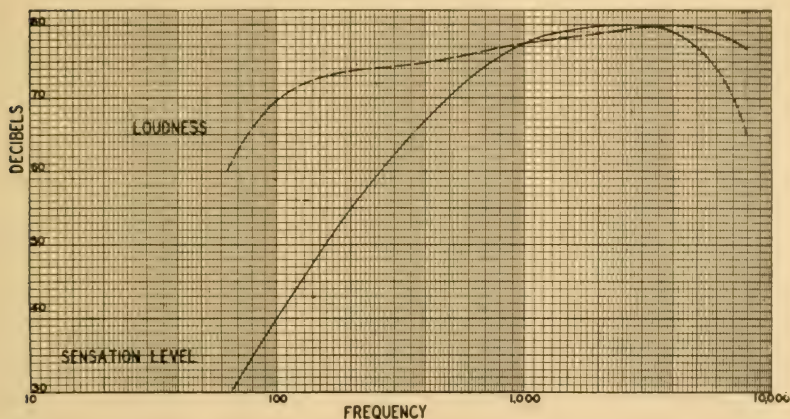


Fig. 1. Variation with Frequency of Loudness and Sensation Levels for Flux of 4×10^{-2} Microwatts per Square Centimeter.

Characteristics of the Electrical System—Amplifiers

The amount of power possible from sound reproducing equipment will depend on the amplifiers incorporated into the apparatus and the efficiency of the loud speakers. We must determine the maximum output power without distortion in quality. The distortion in which we are interested in this discussion is caused by requiring amplifiers to work at overload conditions and is detectable as a certain fuzziness and rattle in the reproduced sounds. Overload involves a non-linear amplification of signals and has the effect of introducing frequencies which may not be contained in the input.⁶ The effect is to be avoided as it reduces articulation and naturalness of speech and tends to destroy quality of music, the degradation in quality being dependent upon the frequency distribution of the extraneous signal.⁷ We conclude that amplifying equipment should be designed to supply the necessary power without encroaching on the non-linear part of the amplification curve.

There are several practiced methods of rating amplifiers. Those made by the Western Electric Company are rated by their electric

⁶Willis, F. C. and Melhuish, L. E.: "Load Carrying Capacity of Amplifiers," Bell System Technical Journal, 5 (1926), No. 4, p. 573.

⁷Steinberg, loc. cit.

output at 1,000 cycles as this frequency lies approximately in the middle of their pitch range and has been found to be a very useful reference frequency. With this method overload is said to occur when the added third harmonic is greater than 1 per cent of the power of the pure sine wave fundamental, in the output. It remains for us to translate this rated capacity of the equipment into something which we can use for complex signals.

For speech the instantaneous peak values of power rise to 20 times the mean.⁸ For example, an accented syllable like "tap" will frequently be distorted in reproduction because the instantaneous power concerned is greater than for most syllables. In amplification it is the peak portions of the signals that are distorted at overload; the tops of sine waves may be flattened. If we assume that the peaks of complex waves are subject to similar effects, we may set a value for speech and music output relative to the single frequency. A ratio of instantaneous to mean power of 20 to 1 gives 13 decibels. Since the maximum of a sine wave is 3 decibels above the average power, then the rating for speech and some types of music should be in the neighborhood of 10 decibels less than that given for single frequency. This output is that which may be compared with the flux of 4×10^{-2} micro-watts per square centimeter selected above. Computation of the rating in this manner is not entirely justifiable since audibility of distortion must be weighed. The type of loud speaker used is another factor. In practice it has been usually found safe to allow a difference of 5 decibels between the maximum mean power of both speech and music and the single frequency rating for high quality amplification. More elaborate experimental work should be done before positive statements in this connection are made.

Characteristics of the Electrical System—Loud Speakers

The electrical energy furnished by the amplifying apparatus must be converted into acoustic energy. The efficiency and faithfulness of this transformation depend on the type of loud speaker that is employed. With exponential horns equipped with receivers like the Western Electric 555, efficiencies as high as 25 per cent are realized.⁹ Thus an attenuation of 6 decibels is introduced in going from electric to acoustic power. If the horns in a theatre are placed behind a screen, power may be lost in transmission and by reflection. The amount varies with the material, porosity, and location relative to the screen, being of the order of 1 or 2 decibels in tests for some screens and up to 5 decibels at 5,000 cycles for poorer ones.¹⁰

We may summarize here and write down the acoustic power actually available for distribution into an auditorium. From the above considerations the acoustic power is about 8 decibels (6 for the horns plus 2 for the screen) less than the electrical, and for complex signals about 13 decibels, that is, 8 plus 5 reserve for peaks, down from the

⁸Sacia and Beck, *loc. cit.*

⁹Wente, E. C. and Thuras, A. L.: "High Efficiency Receiver of Large Power Capacity." *Bell System Technical Journal*, 7 (1928), No. 1, p. 140.

¹⁰Hopkins, H. F.: "Considerations in the Design and Testing of Motion Picture Screens for Sound Picture Work," *Journal Society Motion Picture Engineers*, 15 (1930), No. 1, p. 320.

single frequency rating for reproducing equipment installed in a theatre. Thus a system whose electric capacity is given as 5 watts could produce 250 milliwatts of acoustic power which compares with 40 microwatts for the mean power of loud vowels in ordinary conversation.

Another important element with loud speakers is the distribution of their energy. Most speakers are directional to some extent in their distribution, the horn type exhibiting this property to a marked degree.¹¹ We consider this rather desirable in theatre work as it enables placement of sound energy where it will do the most good. It serves as a tool in meeting the problem of distribution in large auditoriums since much reverberation cannot be utilized without loss of definition. However, care must be exercised to see that some areas are not penalized because of too great intensities on the axes of the horns. This may be illustrated by assuming 3 areas of 1 square foot each with sound at a sensation level of 80 decibels over all of them. If, through faulty distribution, one of the square feet were increased to a level of 83, both of the remaining two unit areas would be necessarily reduced to 77 decibels, assuming more power were not available.

Auditorium Factors

Auditorium acoustic factors must next be considered. It remains to calculate the power required to produce adequate levels of sound intensity throughout a theatre. This power should depend in some way on the volume and shape of a theatre, the seating area, and the acoustic absorption of the surfaces. The absorption present and the configuration determine the influence of reflected energy; the seating area is the surface over which satisfactory conditions are desired. It might be expected that with all these variables weighted, the required power, in general, will increase with the cubical content; that is, the power should be expressible as a function of the volume, perhaps a constant times the volume to an exponent less than unity.

Ordinary reverberation theory, assuming a uniform distribution of acoustic energy, leads to the following relation between the equilibrium condition of sound energy in a room and a source of constant output:

$$e = \frac{4E}{CA} \quad (1)$$

in which e = Average energy per unit volume at steady state.

E = Acoustic power of source.

A = Total acoustic absorption of room.

C = Velocity of sound.

In words, the formula states that if we measured the over-all average energy in an enclosed space, we would find it to be directly proportional to the power of the source and inversely proportional to the absorption in the space. Knowing the energy density throughout the room it is possible to calculate the sensation level of the sound.

¹¹Blattner, D. G. and Bastwick, L. G.: "Loud Speakers for Use in Theatres," *Journal Society Motion Picture Engineers*, 14 (1930), No. 2, p. 161.

In decibels above threshold this is just ten times the logarithm of the ratio of the maintained energy to the energy at zero audibility:

$$L = 10 \log_{10} \frac{4E}{CAi} \quad (2)$$

i = energy density at threshold.

From this formula it appears that, if equal conditions of loudness are desired in all theatres, the necessary power should vary directly as the acoustic absorption present. Thus, a theatre having 10,000 units of absorption (corresponding to a volume of about 280,000

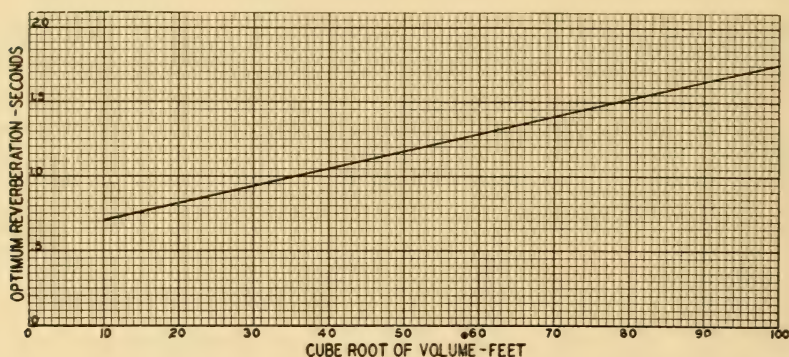


Fig. 2. Optimum Reverberation Time and Cube Root of Auditorium Volume.

cubic feet for optimum reverberation) would require a sound reproduction system having twice the capacity of one that was adequate for a house with only 5,000 units of absorption (120,000 cubic feet). Another slant is that, on the basis of this theory, the same

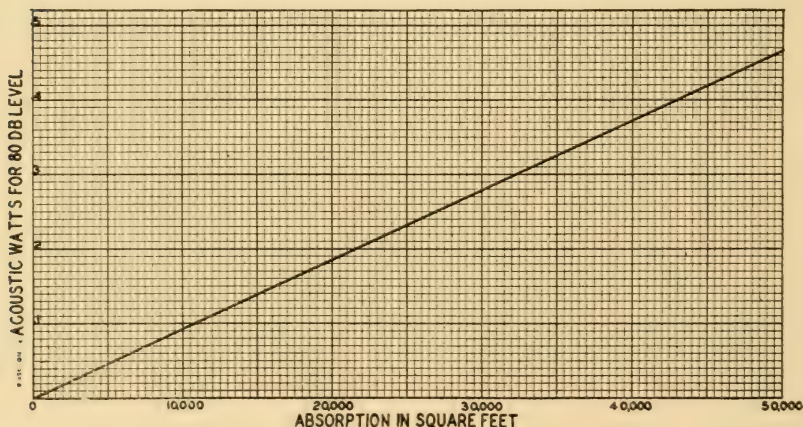


Fig. 3. Acoustic Power for Level of 80 Decibels above 4×10^{-10} Microwatts per Square Centimeter as Function of Absorption.

equipment installed in these two houses would create hearing levels differing by only 3 decibels, a difference which is little more than just distinguishable to the ordinary ear.

Attempts have been made to make the optimum absorption for theatres the yardstick for power capacity of reproducing equipment possible to install with satisfactory results. From the relation between optimum reverberation time and volume of auditorium, it is possible to compute a curve connecting volume and most desirable amount of absorption.¹² Hence, curves 2 to 4 may be calculated to show a theoretical relation connecting powers to produce a level of 80 decibels in auditoriums of different volume, assuming optimum absorption and a threshold flux of 4×10^{-16} watts per square centimeter. From the curves, and what we have already reviewed concerning amplifiers, limits for size of theatres and capacity of reproducing equipment could be established.

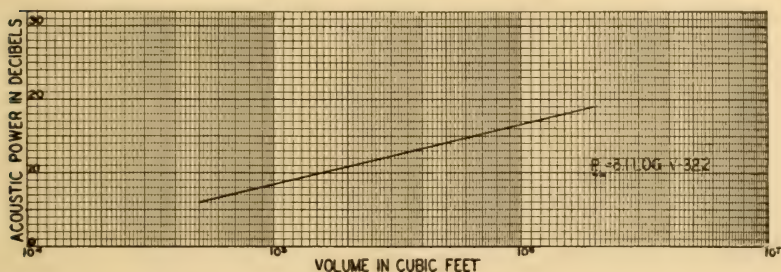


Fig. 4. Estimated Acoustic Power in Decibels above .006 Watt as a Function of Volume Assuming Optimum Absorption.

Fig. 4 shows the required acoustic power in decibels above 0.006 watt plotted against a logarithmic scale of volume. The variables are considered logarithmically since loudness and sensation level are logarithmic functions of acoustic power. It is apparent that over the limited range in which we are interested the equation rather exactly expressing the graphed relation is:

$$P_{ab.} = 8.1 \log V - 32.2. \quad (3)$$

The value of 8.1, as the slope, indicates that the power in watts will increase as V , in cubic feet, to the 0.81 power. Corresponding to this logarithmic expression is the following for the acoustic power in microwatts:

$$P = 3.64 V^{0.81} \quad (4)$$

From what we have previously established, it follows that the electrical must be about 8 decibels above, and the amplifier single frequency capacity some 13 decibels above the acoustic power.

¹²Wolf, S. K.: "Theatre Acoustics for Sound Reproduction," Journal Society Motion Picture Engineers, 14 (1930), No. 2, p. 151.

The premises of the theory leading to the above equation should be examined to obtain an accurate estimate of the conclusions reported in the preceding paragraph. The formula,

$$e = \frac{4E}{CA},$$

expresses the average conditions existing when a sound source of constant power is in equilibrium with the absorption of energy at the surfaces enclosing a room. The average is to be understood as the total energy in the enclosed space divided by the volume. The condition of equilibrium means that a steady state must be reached before the equation holds true. It can be shown that the time necessary for conditions to approximate the steady state is something greater than 0.3 second for most theatres. In speech the consonant portions of the syllables require only about 0.05 second for enunciation, the vowel sounds about 0.2 seconds.¹³ Therefore, application of the equation to obtain loudness produced by speech sounds is open to doubt as the times dealt with are rather too short for the assumptions to apply in all but the smaller volumes. Furthermore, the theory assumes random distribution while it is desirable to have sound reach the audience directly from the screen if illusion is to be maintained. Calculations have been made showing that loudness at points in an auditorium is affected less than 5 decibels by helpful reflections.¹⁴ The impression of loudness is obtained mostly from direct energy, especially with directional sources such as horn speakers. Accordingly the absorption present cannot be correctly indicative of sensation level.

The formula obviously breaks down in the limiting case of open air theatres, or in enclosures where the surfaces are nearly 100 per cent absorbent as here a modified inverse square of distance relation applies. As wall surfaces are made more absorbing, the assumptions necessary for the derivation of the formula are less applicable. Several writers have advocated acoustically "dead" theatres.¹⁵ In this event, loudness, and consequently amplifier output to produce it, must be figured on some other basis as we shall see in the next section.

If we do not accept the absorption theory as a criterion, we must seek a new basis for a computation of the required acoustic power. Another starting point for the theoretical calculation would be the area occupied by an audience and presented to the horn to be covered. Thus, if uniform distribution could be achieved, a reproducing system with an acoustic capacity of 200 milliwatts could produce a sensation level of 80 decibels over an area of 5400 square feet, neglecting any aid from reflection. The same system with proper distribution would produce a level of 77 decibels over twice the area, 10,800 square feet.

¹³Crandall, I. B.: "Sounds of Speech," Bell System Technical Journal, 4 (1925), No. 4, p. 586.

¹⁴Petzold, E.: "Elementare Raum Akustik." 1st Ed., Bauwelt-Verlag, Berlin (1927), p. 74.

¹⁵Kellogg, E. W.: "Some New Aspects of Reverberation," Journal Society Motion Picture Engineers, 14, (1930), No. 1, p. 96. Watson, F. R.: "Acoustics of Buildings," 2nd Ed., John Wiley and Sons, New York (1930), p. 58.

But, obviously, area alone cannot be made the sole factor; the distribution must be uniform and effective. Accordingly, it would be better to speak of "effective area" rather than "area" where the term "effective" should weight the efficiency of direct covering and any aid from reflection.

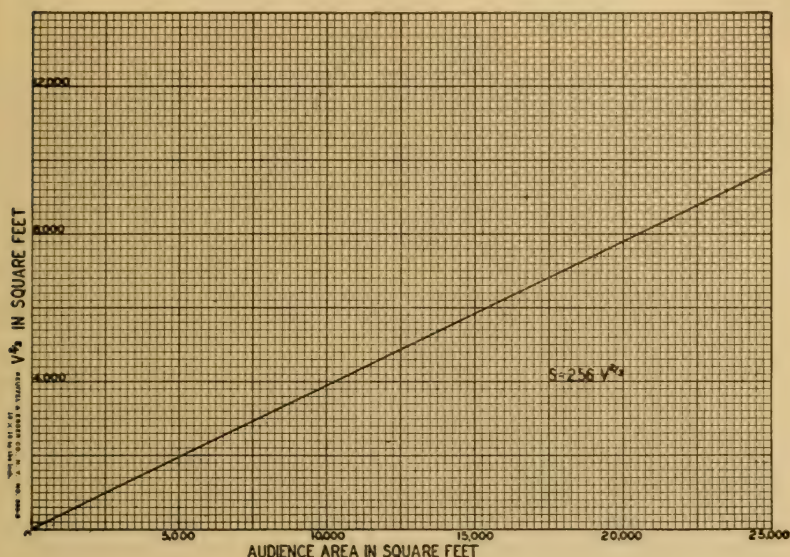


Fig. 5. Relation between Area Occupied by Audience and Auditorium Volume to the Two-thirds Power.

We may assume that effective area will be a function of the seating area and hence vary in some manner as the volume of theatres. Fig. 5 represents the variation of seating area, including aisles and crosswalks, with volume to the two-thirds power. The relation is suggested by the geometrical consideration that on an average the surface of enclosures increases according to the square of the cube root of the volume. Of course, over a large number of theatres there will be considerable deviation from the values indicated by the curve, but a general average is of interest and serves our purpose. The equation connecting volume and seating area is:

$$S = 2.56 V^{2/3}. \quad (5)$$

If we assume that aid by reflection just compensates for the increase of power that would be needed because of faulty distribution, then the effective area will be equal to the audience area. A refinement of the theory, which we have not attempted as yet, might consider some application of the inverse square law. The acoustic power in microwatts required to produce a sensation level of 80 decibels in an auditorium would be, from equation (5) and the desired flux per square foot,

$$P = 95V^{2/3} \quad (V \text{ in cu. ft.}) \quad (6)$$

The acoustic power in decibels referred to 6 milliwatts as a zero level is shown in Fig. 6. The relation is:

$$P_{ab.} = 6.7 \log V - 18. \quad (7)$$

The exponent of the volume here, 0.67, compares with the value of 0.81 obtained on the premise that the optimum absorption should govern the required power.

Empirical Results

In order to check the theoretical conclusions outlined previously we conducted tests in nine theatres. The electric power for speech supplied to the horns was measured by a power level indicator. The corresponding sensation level created in the theatre was measured by means of a portable intensity meter designed by the Bell Telephone Laboratories, which need not be described here in detail. This meter had a frequency characteristic similar to and was calibrated against the human ear. The theatres were selected to cover the volume range from ten thousand to a million cubic feet and were of different architectural types, varying from single floor to orchestra plus two bal-

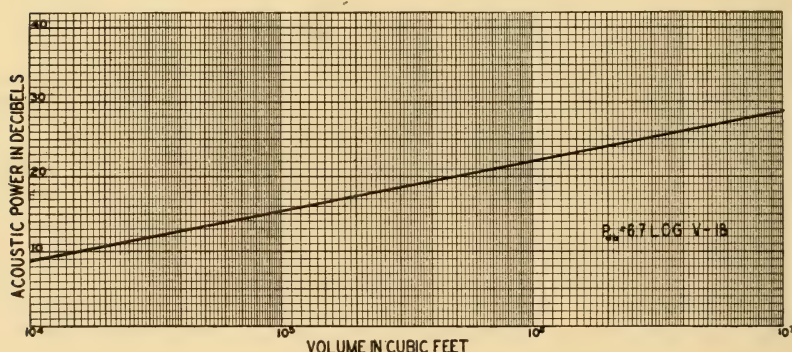


Fig. 6. Estimated Acoustic Power in Decibels above .006 Watt as a Function of Volume on the Basis of Seating Area.

conies. Six of them had less than optimum absorption. The microphone pickup of the intensity meter was placed in several locations to insure a satisfactory overall average for each house. However, in most instances the distribution was quite uniform. The measurements were made with comparatively few people present for the most part.

Readings were taken throughout a range of about 30 decibels. For each theatre the observed sensation level was plotted against the corresponding amplifier output. A representative plot is shown in Fig. 7. By extrapolation it was possible to arrive at the power required for a sensation level of 80 decibels. These values for all the theatres were then plotted against volume leading to the relation shown in Fig. 8. The equation in this case is,

$$P_{ab.} = 7.3 \log V - 21.8. \quad (8)$$

In microwatts the equation is,

$$P = 40V^{.75}. \quad (9)$$

Our measurements disclosed that ordinarily the sensation levels for speech fluctuated about an average of 65 decibels. On the occasions when the level fell below 60 decibels, intelligibility was difficult and listening a strain, especially at the higher audience noise intensities.

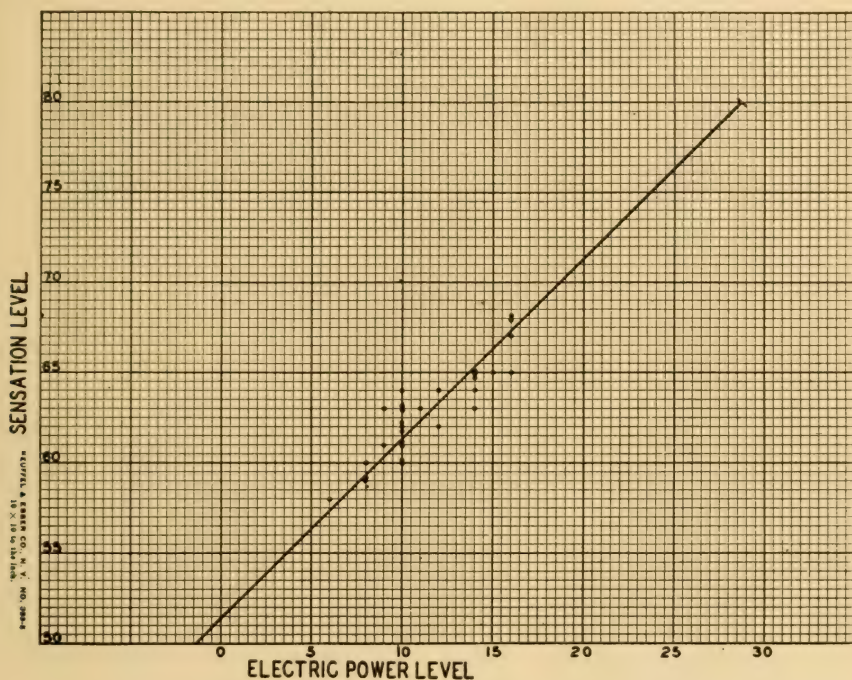


Fig. 7. Representative Plot of Observed Electric Powers and Resultant Sensation Levels.

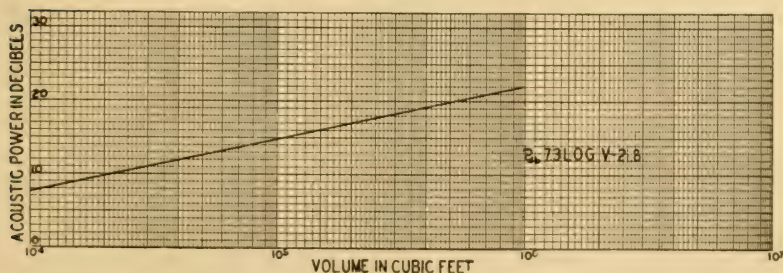


Fig. 8. Acoustic Power in Decibels above .006 Watt as a Function of Volume from Experimental Data.

The limit of 80 decibels was attained by machine gun fire, cheering, and similar sounds. Our experience is that this level seems very loud, especially when sounds are sustained over periods of time long compared to the time for syllable enunciation. The fact that they are in contrast to sounds ordinarily about 15 decibels lower probably promotes such a conclusion. Signals with a large portion of their energy in the lower frequencies did not reach these levels, as we expected. However, their loudness was adequate.

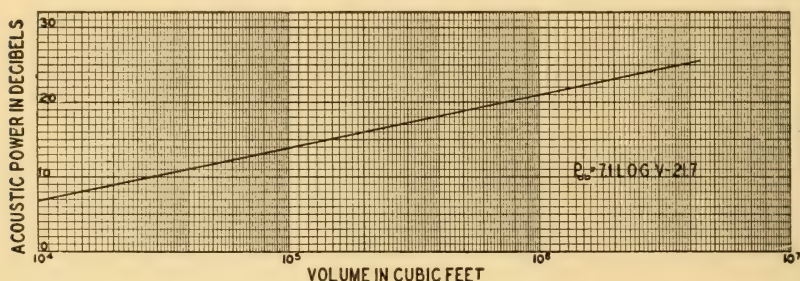


Fig. 9. Acoustic Power in Decibels above .006 Watt as a Function of Volume from Public Address Data.

Data on public address systems collected by D. G. Blattner and J. P. Maxfield of the Bell Telephone Laboratories is substantially in agreement with the above. Measurements made by several observers of the electric power into the loud speakers at optimum audition in auditoriums of different cubical content. Because of the manner of making the adjustments, the sensation levels produced should correspond to those considered satisfactory for ordinary speech reception in a previous section of this paper. Making this assumption, it is possible from the observed volume indicator readings to compute the power necessary for a flux of 4×10^{-2} microwatts per square centimeter. The results shown in Fig. 9 indicate that the required power increased according to the volume to some exponent of the order of 0.71. The algebraic relation is,

$$P_{ab.} = 7.1 \log V - 21.7. \quad (10)$$

The power in microwatts given by,

$$P = 41 \times V^{.71}. \quad (11)$$

Discussion of Results

A comparison of the different results is best accomplished by graphical means. Fig. 10 shows the four curves for the acoustic power required for an 80 decibel level relative to the threshold value of 4×10^{-10} microwatts per square centimeter, calculated on the basis of seating area, on the basis of optimum absorption, and obtained experimentally. The two empirical curves lie between the others, as might be expected, with the seating area relation representing the better approximation to them. Their slopes, 7.3 and 7.1, which are

of as much interest as the actual magnitudes of the power, are also nearer to 6.7, the slope of the upper curve, than they are to 8.1. The empirical curves differ most from are a relation at the lower end. The inference is that for smaller volumes somewhat less power is required because reflections play a more useful part and steady state conditions are more closely approached. This seems to check our view that absorption in theatres cannot be the correct criterion for computation of power, while it is a factor of some importance.

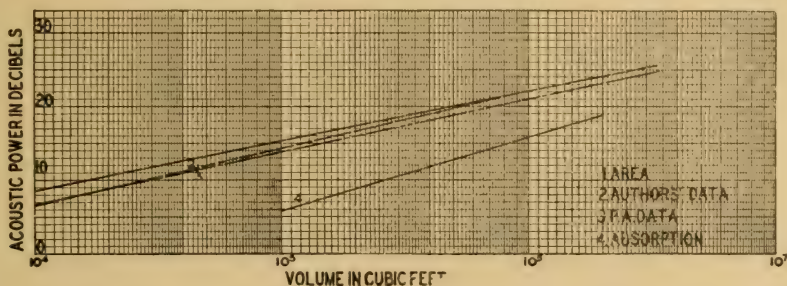


Fig. 10. Comparison of Acoustic Powers for Sensation Level of 80 Decibels.

It should be noted that a straight line probably does not represent the exact relation between acoustic power and volume. Actually we should expect a curve which approaches asymptotically the effective area values and a slope of .67 for large volumes where reflections are of little aid. In the case of smaller volumes there should be a droop toward the absorption relation as reflections play a larger part. Within the range and accuracy worked with, however, it seemed to the authors that a straight line gave the fairest representation of the results.

Considering the nature of the work the agreement among the curves is good and should be regarded as substantiating but not final evidence of the correctness of our conclusions. There are involved many variables which are incapable of sufficiently exact estimation. The results may be used to forecast theatre requirements in most new instances. In practice there must be expected some deviation due to differing structure of auditoriums as affecting the reflection and distribution of sound energy, we have attempted to deal with averages here.

Illustrations below accompany the article on opposite page

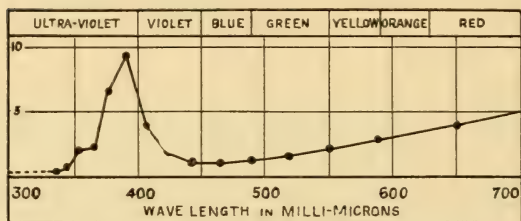


Fig. 1. Spectral energy distribution curve—Plain carbon arc

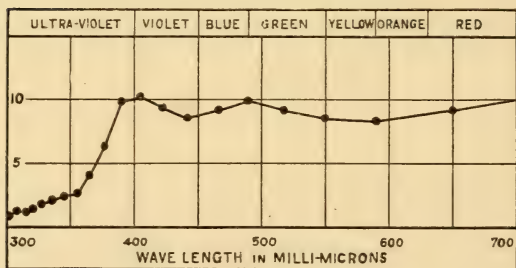


Fig. 2. Spectral energy distribution curve—white flame carbon

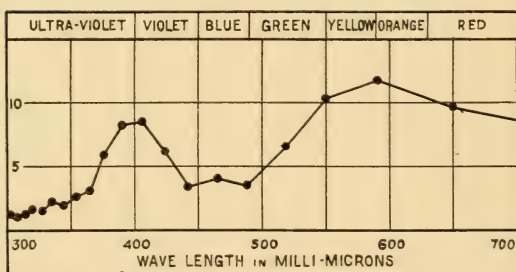


Fig. 3. Spectral energy distribution curve—panchromatic carbon arc

THE USE OF CARBON ARC LIGHTING

With the New Fast Panchromatic Film

W. C. Kalb*

FROM the beginning of the motion picture industry the carbon arc lamp has occupied an important place in studio illumination.

A large proportion of the chemically active radiation from the plain carbon arc is in the blue, violet and near ultra-violet regions of the spectrum. These are the bands of radiation to which all photographic emulsions are most sensitive. Due to this fact, the carbon arc quickly established itself as the most efficient type of studio lighting.

It was soon realized by carbon manufacturers that the photographic effectiveness of the carbon arc lamp could be greatly increased by modifying the distribution of radiant energy to give increased light in the green and yellow bands, where the sensitivity of the film then in use was low.

The distribution of radiant energy from the plain carbon arc is indicated by the curve in Figure 1. By introducing certain flame supporting materials in the core of the carbons, it was found possible to produce a light of much greater photographic power and practically a pure white in color. The spectral energy distribution of the light from this type of carbon, known as the white flame carbon, is shown in Figure 2.

With the brilliant, penetrating light of the white flame arc available, considerable increase in the speed of photography was possible. The lack of film sensitivity to orange and red, however, gave negatives with sharp contrast and necessitated close attention to colors in set and make-up. The degree of exposure needed to bring out the green and yellow reduced the blues almost to white, while still leaving the orange very dark and red practically black. As a result of these conditions, carbon arc lighting came to be spoken of in the studios as "hard" lighting. These sharp contrasts could be softened greatly by the use of filters which cut out a portion of the blue light but this was accomplished only at a loss of speed.

The introduction of the panchromatic negative film brought with it a marked increase in the quality of photography. This film, sensitive to orange and well into the red band of the spectrum, made it possible to record practically the entire range of visible color. The sensitivity, however, remained relatively low in the color band from green to red as compared to that in the blue, violet and near ultra-violet. Distinct color separation and accurate reproduction of color tones required either the use of filters or modification of the light source to supplement those colors where the sensitivity of the film was low, the yellow, orange and red.

* National Carbon Company

To meet the situation created by the development of panchromatic film, a modified form of flame arc carbon was introduced, known as the panchromatic carbon. This carbon produces less light in the blue and violet region than the white flame arc but relatively much more in the yellow, orange and red, as may be seen from Figure 3. It thus supplements the sensitivity of the panchromatic film emulsion, giving less light of colors to which the film is most sensitive and more of those colors to which film sensitivity is low. The use of panchromatic carbons when photographing on panchromatic film eliminates the need for filters, giving excellent color separation and true tone values with all the advantages of exceptional photographic speed possessed by the carbon arc.

The advent of sound pictures was assumed by many to spell the doom of the carbon arc in motion picture studios. It was a relatively simple task to quiet the mechanism of the carbon arc lamp but it was then found that the sensitive microphones picked up a tone from the ripple of current resulting from commutation on the direct current generating equipment supplying power for the lamps. As a result some studios turned immediately to incandescent illumination. This led to another serious difficulty. The power input needed to get equivalent photographic power from incandescent lamps resulted in a many fold increase in heat radiation from the light units with serious discomfort to the actors.

Other studios, recognizing the inherent photographic superiority of the carbon arc, sought means of eliminating the "commutator ripple". It was found that the use of a series inductance of suitable value, with an electrolytic condenser connected across the terminals of the generator, absorbed the fluctuations of current resulting from commutation and gave a quiet arc from which the microphones picked up no disturbing sound. The number of successful current productions photographed under carbon arcs is ample proof of the fact that carbon arc lighting can be readily adapted to sound pictures.

The recent introduction of the new fast, panchromatic, negative film broadens the scope of the carbon arc in studio illumination. This new film is much faster than former emulsions over the entire color scale but especially so in the orange and red. This increased sensitivity to the longer wave lengths lessens the need for color compensation in the source of illumination. Photographic tests indicate that scenes embodying a full range of color or those in which greens are dominant can be photographed with very good color separation in the light of the white flame carbon arc. This light is very close to natural daylight in spectral energy distribution and gives practically identical photographic results.

For scenes in which yellow, orange and red predominate there might be some advantage in the use of panchromatic carbons with this new film, thus getting the full benefit of the increased sensitivity to longer wave lengths in attaining maximum photographic speed. In general, however, these photographic tests indicate a tendency toward over correction when panchromatic carbons are used with super-sensitive film—dark blues and very light reds. Some photographers have

reported that their experience indicates the use of a combination of white flame and panchromatic carbons for attaining best color rendition with the new film.

It would seem that, with this new film and the color control possible through the use of white flame carbons, panchromatic carbons or a combination of the two, no filters should be required except to attain unusual photographic effects.

Sufficient data on this new emulsion are not yet available to permit of exhaustive scientific comparison of the results obtainable from different sources of illumination. However, a series of test photographs, made to determine the relative speed of the supersensitive film with different light sources of the same power input, gave the following indications. The subject was a chart composed of several bands ranging from white through increasing depth of gray to black. Equal depth of negative was obtained with exposures in the relation of 10 for the white flame carbon arc, 12 for the panchromatic carbon arc and 30 for incandescent illumination from 1500 watt units. These ratios would be modified somewhat by the introduction of color, the direction of modification depending on the predominating colors. In all cases, however, the carbon arc gives from two to several times the photographic power of other light sources of equal line wattage.

It is evident from the preceding paragraph that the increased comfort of the stage, made possible by the use of super-sensitive film with consequent reduction in volume of illumination, is attained to the fullest extent only by the use of carbon arcs. And there is no question but that maximum comfort for the actors is bound to be reflected in the quality of the production.

The emphasis now being given to economy in motion picture production lends new importance to every element of cost reduction. The carbon arc offers a means of substantial saving in illumination cost to those studios now using other types of lighting units. Conservative estimates disclose the fact that the use of carbon arc illumination results in economies in interest and depreciation on investment, repairs and upkeep, replacement of carbons versus replacement of depreciated or broken units of other types, and cost of electrical power for equivalent photographic light. These economies are effected without any increase in cost of attendant labor.

The carbon arc used in conjunction with the new fast, panchromatic film, offers to the studio a superior quality of photography, adaptability to sound as well as silent pictures, remarkable photographic speed, accurate reproduction of daylight illumination, flexibility in color quality without the use of filters, maximum stage comfort and lowest illumination cost. These are factors which merit, for the carbon arc, the most careful consideration on the part of motion picture producers.



The Cutter

Gaston Longet

MOTION PICTURES MUST MOVE

William A. Seiter

EVERY CLOUD has a silver lining. During the business depression which has affected the entire world, the motion picture industry has been forced to produce fewer pictures because of economic necessity. As a result the year 1931 has brought fewer—but better pictures.

Once again the real motion picture has come into its own. Once again we are making motion pictures,—pictures that move. After two years of floundering and groping for the proper medium of new pictorial expression, the picture-makers have had to go back to the original fundamentals of the motion picture art.

We are now “shooting” pictures instead of photographing plays. Necessary action has supplanted trite dialogue. In other words, we have at last hit upon the happy medium in making a picture that talks.

Originally, the motion picture was divided into four parts: pantomimic acting, physical action, story and photography. With the invention of sound, the voice of the actor was added to acting and sound was added to action. In the beginning, most of the picture-makers got off on the wrong foot. “Talking pictures” became the rage, and in most cases we had nothing but talk, talk, talk. The industry went batty on the subject of dialogue, just as it did later on the subject of music. There was no dividing line, no balance. In the mad struggle to master the new medium, the motion picture was forgotten. The picture ceased to move, and after the theatre audiences became accustomed to the thrill of hearing sound, they too ceased to move—into the theatres.

Audiences became fed up with watching and listening to actors who did little but exchange interminable lines. Even the cleverest wise-cracks began to pall on jaded nerves. Theatre business began to slump.

And, in the meantime studios were conducting costly experimentation in desperate efforts to find out what was wrong. From the beginning, I honestly believe that there were quite a few directors, producers and writers—those who had been making pictures for years—who intuitively knew what was wrong. They knew instinctively that the appeal of the motion picture had been lost by an overdose of talk. They knew that the so-called “talking” pictures would have to be discarded in favor of the motion picture that talks.

One of the most significant indications of the trend of public taste came in the sudden comeback of the old western thrillers to popularity. The old western movies had action. As a western story could hardly be made without action, the picture-makers speedily discovered that lack of action had been one of the ailments affecting all pictures.

Along came the gangster pictures. Once more a tremendous wave of popularity that swept the audiences back into the theatres. Why?

They had action plus. Gangsters, like all men of action, were men of few words. The dialogue was crisp, dramatic and to the point. These pictures moved, and even though they weren't the best subjects in the world for young people to see, they certainly served a most valuable purpose in proving to everybody concerned what had been wrong with the motion picture.

Pictures like "Little Caesar," "The Public Enemy" and "The Star Witness" are outstanding examples.

The epic sweep and action of that great picture made by Wesley Ruggles and produced by Radio Pictures—"Cimarron"—proved conclusively that once again we were on the right track.

In common with most directors, I have always held that we must never forget we are primarily making motion pictures. That action must have an equal place in pictures with brilliant dialogue and acting. Now that we seem to have hit upon the happy medium the picture industry ought to go places during the coming season.

It is not my intention in this article to deprecate the value of dialogue. It was the spoken word that gave pictures a new lease on life. We all know that sound came along at the crucial moment, when the silent movies were in the doldrums. Personally, I have always thought that the new picture is a vast improvement over the old. At times, looking at scenes from old silent pictures in studio projection rooms, I have marveled at the vast improvement in entertainment values.

If it weren't for the invention of sound in pictures, thus making possible the enjoyment of the human voice in acting, we never would have lured the most able playwright, novelists and dialogue writers to Hollywood. Or, the leading singers, musicians and composers of the world. Even if musical pictures were a drug on the market, I concur in the firm opinion of William LeBaron that they are due for a sensational comeback. Picture-makers will once again strike a happy medium in producing this type of picture. We all know now what was wrong. That the motion picture public didn't understand or like musical comedies and operettas presented exactly as they were on the stage. The motion picture public, particularly in the small towns, knew nothing of stage traditions. No wonder they couldn't understand why a singer should suddenly burst into song in the middle of a scene, for no reason at all. When we get around to producing musical stories logically, then musical pictures will regain their popularity. It would be a crying shame if such artists as Lawrence Tibbett and Marilyn Miller were lost to pictures for want of the proper medium of expression.

Occasionally it is possible to find a play, depending solely upon the brilliance of dialogue and the novelty of plot, which will make a successful picture. Such are "The Front Page," that rollicking newspaper story of Ben Hecht and Charlie McArthur, directed so intelligently by Lewis Milestone; "Street Scene," Elmer Rice's novel and sordid drama of the tenements so keenly interpreted by King Vidor; and "Bad Girl," the Vina Delmar human love story so beautifully done by Frank Borzage. But—how many such plays may be found?

And, in each case the novel treatment evolved made the picture. For example: Lewis Milestone succeeded in maintaining such an amazingly fast tempo in "The Front Page" that the rapid-fire dialogue took the place of action.

Realism has always been the keynote of the motion picture. In the development of the old silent movies the successful directors stressed realism so thoroughly that there was little left to the imagination. By blending story, pantomimic acting, direction and photography we painted a picture so clearly, so realistically that the audiences could relax and enjoy themselves.

When the sound invention came along, and the element of the human voice was added, realism was temporarily forgotten. Apparently everyone concentrated upon dialogue. Plays were photographed and directed exactly as they were presented on the stage. Naturally, the results were mediocre. Most of the early pictures of this type were incoherent, unimaginative and deadly dull.

Audiences became distracted and bored with the torrent of words which poured from the mouths of actors on the screen. Gone was the enjoyment and relaxation of watching the artistic beauty and realism of pantomime. Audiences left the theatres exhausted from being forced to listen so intently to every word in order to get the meaning of the story. And, often they left the theatres confused and disgruntled. They missed the realism that had been the keynote of the motion picture.

However, in defense and praise of the picture-makers I must say that no time was lost in finding out and correcting what was wrong.

It took at least a decade to develop the old silent picture to a state of near-perfection, and I feel that the picture industry has succeeded in developing the new type of motion picture to a much higher standard of entertainment in a short three years. And this work was and is being done during the worst years of business depression we have ever had in this country.

Today, the successful motion picture blends the component elements of the art—story, dialogue, acting, direction and photography—in a well-balanced manner. No one element can be sacrificed for the sake of the other. Once again we are presenting pictures so realistically that the audiences can relax and enjoy themselves.

Dialogue is becoming as human and realistic as the acting. For example: in my opinion, the dialogue written by Edmund Burke in Frank Borzage's production of Vina Delmar's "Bad Girl" is the epitome of humanness and realism.

In closing, a word must be said in praise of the remarkable development in the mechanics as well as the technique of the new motion picture. Sound equipment has become so improved during the past two or three years that picture-makers would be sad failures indeed if they had failed to keep pace with these wonderful inventions.

For the coming year, 1932, I will venture to predict that the musical picture will come back: stage traditions will be discarded, and realism will reign supreme.



In the Carlsbad Caverns

Hatto Tappenbeck, A.S.C.

OPTICAL PRINTING

*Lloyd Knechtel**

WITHIN the past few years the motion picture industry has almost universally adopted the system of optical printing in its many and varied uses and forms, and has found it invaluable as both an artistic and an economic aid. Optical printing may be defined as a printing method which produces duplicate motion picture negatives or positives optically rather than by contact. In other words, it is more nearly akin to the still photographer's familiar process of copying than to true printing, for the scene is actually re-photographed from a previously made positive or negative. Perhaps the clearest idea of the process, however, can be gained from a brief description of an optical printer.

In the first place, the optical printer, unlike any other photographic apparatus, usually has its own source of power-supply—a motor-generator set, generally supplying direct current. This is to assure an even flow of power for the printing-light and driving-motors, free from the inevitable fluctuations that occur if power is taken from the usual studio lines. The optical printer itself is in every case designed to suit the individual requirements of the cinematographer operating it, and built with the utmost precision. In most cases an ordinary lathe bed is used for the foundation, not merely because it offers ready-made the most suitable unit, providing all of the necessary basic adjustments, but because its precision design and rigid construction provide the absolutely solid foundation that is vital in high-grade trick and multiple-exposure work, where maximum steadiness and accuracy are required. The actual mechanism itself consists of two units: a printer-head, or rebuilt camera mounted at one end of the bed, and a regulation photographing camera at the opposite end. Both of these are motor-driven, and their action is mechanically interlocked.

The printer-head is essentially a lensless projector, as it consists of a light-source, an intermittent film movement, and a means of carrying developed film—usually positive. In order to ensure absolute accuracy, however, this intermittent movement is usually either a rebuilt camera, or at least a camera-movement, equipped with registering-pins.

Assuming that the film used in the printer-head is positive, the regulation camera rephotographs this positive while held in a still position by the registering-pins. During this photographing, the shutter on the camera-head is naturally open. Since the movements of the camera and printer-head are mechanically synchronized, when the positive film is being moved on to the next frame, the shutter of the photographing camera is closed, and an unexposed frame therein being brought into place. By this means, since the movements of both the positive film in the printer-head and the negative film in the

*Head of Special Effects Department, R-K-O-Radio Studios.

camera-head are positively synchronized, the result is a steady duplicate picture. In order to gain certain special effects, special gearing is provided in this synchronizing hook-up, whereby the synchronism may be varied from this normal, so that if it be so desired, a single frame of the positive may be photographed on as many frames of the negative as may be necessary, or, conversely, every alternate frame, of the positive, or every third frame, or any other desired combination may be photographed on successive frames of the negative. If it is desired, the printer-head may be run backwards, while the camera runs forwards, reversing the action.

Probably the most common use of optical printing is in the making of lap-dissolves. Due to various mechanical factors introduced by sound, it is an absolute necessity in most cases where sound is used to make these dissolves at a later date rather than in the camera on the set. And since this necessity has forced us to make all dissolves optically, we have found that this method is by far preferable; perfect timing of dissolves may be had, with the constant option of changing them to comply with all possible re-cutting of the production. Therefore while in the old days much time and labor was wasted because the production cameraman was saddled with the responsibility and worry of making intricate lap-dissolves and multiple-exposures on the original negative at the time of photographing, today all of this complicated technical work is handled by a separate department specializing in this work, which might be termed "post-photographing". The production cameraman now simply photographs his scenes in the regular manner, with the lightings with which he normally works. He is required to adhere to certain simple requirements that will assure the suitability of his shots for optical after-treatment. Then, after the film has been developed and printed, the Special Effects Department takes charge of it, inserting whatever dissolves, lap-dissolves, or multiple-exposure effects may be required.

In this branch of cinematography the laboratory takes on added importance. A print which is to be rephotographed must have certain definite characteristics. It must naturally reproduce faithfully all of the fine detail and gradations of the original negative, and must moreover be of just the precise density and contrast that are best suited to optical printing—and which are quite different from those best suited to normal projection. Equally important is fineness of grain both in the positive master-print and in the resultant duplicate negative. To this end the laboratory technicians must not only keep abreast of the latest technical developments in their craft, but be individually experimenting with new and specialized developers themselves. Furthermore, even the routine processing of film intended for optical printing must be carefully supervised by conscientious and expert technicians, who realize that perfection is composed of trifles, and that perfection itself is no trifle.

There are ever increasing demands made on the optical printing experts to "doctor up" scenes that have already been photographed and which require certain "adjustments" in order to make them usable in a production. By careful manipulation on the optical printer

it is frequently possible to so improve defective scenes that it is not necessary to retake them—consequently saving the company considerable amounts of money, to say nothing of time and effort. Although modern first cinematographers and laboratory technicians are seldom at fault, it does occasionally happen that a certain piece of negative is through some mischance incorrectly exposed or developed. In such cases—particularly in underexposure or underdevelopment—the fault may be cured, or at least greatly improved, by the use of the optical printer in making a richer duplicate negative. In a similar manner, harsh or over-contrasty negatives may be made softer and more pleasing to the eye. Day scenes may sometimes be skillfully blended with special filters and converted into passable night scenes. Objectionable details—such as signs, especially—may be “dodged” so as to appear hazy and indistinct. If a scene does not have sufficient footage for dissolves or double-exposures, a few frames—or even a single frame—may be successively rephotographed to stretch it out to the desired length. For some certain effects a scene may need to be magnified or reduced: this may be done with great flexibility and ease on the optical printer. During last year’s wide-film experiments it was found that scenes made on standard film could be successfully enlarged to fill the larger frames, or, conversely, that scenes made on wide film could be reduced (either maintaining the wide, low frame proportion or not, as might be desired) to standard film. At least two firms actually released wide-screen pictures on standard 35mm. film through this process.* In industrial work, 35mm. pictures may be reduced to 16 mm. by the optical printer. By means of special “zoom” lenses, ordinary long-shots may be converted into approaching or receding travelling shots, and miniature sets and shots may be imperceptibly merged into full-scale shots. Action may be reversed by making a duplicate negative of the proper degree of sharpness and reversing the positive film before photographing.

A good example of the variety of things demanded of the optical printing department by even a simple script is given by a recent Richard Dix picture. In addition to supplying all of the fades and lap-dissolves in the picture, the Special Effects Department was called upon for the following: In a miniature train-wreck sequence, it was necessary to rephotograph the scene to obtain better *tempo*: at the beginning of the scene it was necessary to photograph every third frame of film to speed up the action of the train approaching; then every second frame during the section where the train was reaching the foreground; and for the actual crash, normal speed. There were two crashes used, both scenes having been photographed so that the train approached the camera head-on. These scenes were magnified to a great extent, and rain photographed against a black velvet background was double-exposed over the whole sequence. The two crashes were connected with a quick lap-dissolve in the middle of the crash, and the last scene used placed the miniature cars in the same relative positions on the screen as the full-size wrecked cars used in the normal scenes of the production, and in which scenes many people were used.

* “Billy the Kid,” “The Bat Whispers,” and “Great Meadow.”

The last miniature scene also lap-dissolved into the full-scale scene, giving a highly realistic effect.

A further important use of optical printing is in combining miniatures, painted glass shots, and stock-background shots of distant locations with action photographed on the stages. While this work can never entirely eliminate the necessity for the various travelling-matte processes, such as the Dunning and William processes, or projected backgrounds, it is none the less a most useful expedient. By its use much of the time and effort formerly spent in lining up front miniatures, glass shots, and the like can be eliminated, while the work of both the production cinematographer and the miniature and glass technicians can be greatly simplified. In a recent picture one scene combined, thanks to the optical printer, these components: The main action and the set itself were photographed in full scale on the stage, with dialogue. The sky was put in by means of a glass shot. The background—which contained considerable action—was put in by the Dunning process. The foreground was largely a miniature. And a part of the middle-distance was put in by simple double-exposure. All of these were combined into a single negative by means of optical post-treatment, and the result was absolutely undetectable as a composite—even by experts.

The recent return to silent picture technique has brought again the vogue for using impressionistic cinematic methods for conveying emotional and dramatic points. This again makes new demands upon the ingenuity of the optical printing department. But as long as optical printing is not only carefully executed, but tempered with imagination, the possibilities offered are unlimited. The motion picture is, and always will be, primarily a visual art, and no tool that has yet been made available to the motion picture craftsman has in it greater potentialities for visual expression than the optical printer. In its present form it is capable of almost anything; and it is being constantly improved. There are endless possibilities to the different devices which may be constructed and used advantageously with it: but still more boundless are the possibilities which must be latent in the minds of those who utilize it. For it must not be forgotten that optical printing is more than a mere mechanical craft—more than a mere method of "dodging" and retouching moving pictures: it is in its highest development a creative art, with potentialities quite as great as those already recognized in the realms of the scenarist, director, and production cinematographer. It is not merely a means of remedying their shortcomings, but a means of creating both realistic and impressionistic visual effects which lie beyond their scope. Optical printing, in short, aided by imaginative writing, direction, and sound-montage, is a further means of appealing to the imagination of an audience through the readiest channel—the eye. And as such, even without its more routine, mechanical applications, it is an indispensable part of the intricate machine which is striving to produce better pictures.

THE EVOLUTION OF MOTION PICTURE FILM PROCESSING APPARATUSES

*Joseph A. Dubray, A.S.C. **

THE processing of motion picture films pertains fundamentally to the science of photography and to it applies the same considerations upon which is based the processing of "still" plates or films with regard to the reduction of the latent image into a visible and permanent one.

There is, however, a vast difference existing in the means devised for the physical handling of motion picture films as compared with ordinary photographic plates or films.

The most obvious reasons for these differences are to be found in the shape of the film itself.

A tape form film several hundred feet long, requires obviously different methods of handling than single plates, single films or short rolls of film.

No great difficulty was involved in the solution of these problems from the very beginning of motion pictures, because their solution was to be easily found in constructing appropriate racks for holding the film throughout its processing and tanks of such shapes and sizes to accommodate them with a minimum possible waste of the photographic solutions.

From the very inception of motion pictures it was found, however, that films had to be treated with particular attention as to evenness of processing and with a view to eliminate all possibilities of even the smallest scratches, abrasions and the least accumulation of dirt which irretrievably mar them and cannot be tolerated especially because of the fact that such imperfections are greatly magnified during projection.

This involved mostly precautionary measures and although a good deal of ingenuity had to be displayed by pioneer laboratory experts, no great difficulties were to be found in order to solve the problems involved.

It was, however, soon found that other factors were to be taken into serious consideration, factors which involved what can be termed as the mechanical characteristics of motion picture films and their behavior during and after processing.

The study of these characteristics and the discovery of means to control the errors inherent to them, involved long painstaking investigation and engaged from the very beginning the earnest attention of technical researchers. These investigations conducted at first, somewhat at random, proved in due course of time to be so essential to the advance of motion pictures and so replete with difficulties that they attracted the attention of men of science throughout the world.

Manufacturers of motion picture films and motion picture equipment, established research laboratories, whose work has steadily increased in importance and from which are brought to the attention

* Manager Technical Service Dept., Bell & Howell Company.

of the motion picture world the basic principles upon which are based the whole of the technical structure of motion picture production.

It would seem at first thought, that once standard dimensions as to size of film, size and spacing of perforation, and dimension of picture frame are established, the task of conceiving and constructing apparatus to handle it throughout its processing, should not present other difficulties than those inherent to accuracy of design and manufacture, and such would indeed be the case if motion picture film was a stable material.

Unfortunately, however, the celluloid base of films is subject to stretching and shrinkage, according to its moisture content, and to the atmospheric conditions in which it is placed.

This stretching or shrinking of the film is, furthermore, beyond human control and even when films are manipulated with the most exact care, the changes in dimensions which result from these phenomena offer a multitude of serious problems, the solution of which has been the goal of the motion picture mechanical engineer.

If we consider a roll of film at the moment that it leaves the manufacturing plant, we can consider it as being cut and perforated to the exact dimensions which have been accepted as standard.

This roll is carefully packed in proper wrapping material and in sealed cans under ideal conditions of temperature and humidity, and it is reasonable to expect that under such conditions, its dimensions will remain unaltered until the time that it is withdrawn from its container for use. Then the following conditions are to be contended with:

1. Shrinkage occurring from dryness from the time that the film is withdrawn from its container and the time that it is run through either camera, printer, and developing solutions.

This shrinkage effect can in practice be disregarded for positive film because it never leaves the laboratory rooms where atmospheric conditions are kept under control.

Negative film may shrink sufficiently to create some trouble, especially if left in the camera magazines for a length of time or used under conditions of extreme heat, cold or high degree of humidity.

2. Swelling and stretching during the wet processes of developing, fixing, washing.

3. Severe shrinkage during the process of drying.

4. *Continued* shrinkage after the film is completely processed.

Positive films are obviously more liable to be seriously affected by shrinkage because of their long running through projection machines and their constant exposure to variable atmospheric conditions, while negative films are stored away with special and utmost care, and their shrinking takes place mostly during the relatively short time that they are run through the printing machine.

It is seen from the above that, since the film is run through the various apparatuses only when dry, the shrinkage effect is more troublesome than that of swelling and stretching.

It is quite true that the changes of dimensions which result from shrinkage are small and that reasonable care can maintain them so, at least within the walls of the processing laboratory. In spite of their smallness, they are, however, of great importance because any error of registration due to these errors is greatly magnified during projection and cannot be tolerated but within extremely small limits.

The problems that the mechanical engineer confronts with those conditions would not present extreme difficulties of solution if film shrinkage could be predetermined and, therefore, controlled. But such is not the case. Although films taken from the same roll of celluloid base and handled under equal atmospheric conditions offer equal shrinkage characteristics, no two films taken from rolls of celluloid made at different times or exposed to different conditions of heat or cold or dryness or humidity, shrink to the same extent. Therefore, the mechanical problems are greatly multiplied.

In fact, film shrinkage cannot be *controlled* but only *accommodated* and certain limits of error had to be determined beyond which accommodation is impossible in practice.

The problems resultant from film shrinkage became evident from the very inception of motion pictures and their complexity became more and more apparent with the rapid progress made in commercializing the new discovery.

It is quite interesting to note that these problems were attacked from two points of view in Europe and in America.

European manufacturers attempted to accommodate shrinkage by varying the dimensions and pitch of perforations for negative and positive films.

Since negative film shrinks considerably, during the drying after the wet processing, an average percentage of shrinkage was determined and positive film was perforated to accommodate both the longitudinal and the lateral changes of dimensions suffered by the negative.

Perforating machines manufactured in Europe were so devised that the punches and dies for the two dimensions were interchangeable.

When the shrunk negative and the unshrunk positive were run through the printing machine, this being of the step-printing type, the driving fingers would bring two sets of corresponding perforations into coincidence, while a pressure plate would assure contact and stability of positioning.

This method of registering, though fairly accurate, cannot be relied upon for critical register under shrinkage conditions varying from the predetermined average and, of course, the greater these variations, the greater would be the error in registration.

It was A. S. Howell of the Bell & Howell Company of Chicago, who first conceived and constructed a printer in which he replaced the intermittent motion of the films with a continuous motion, which

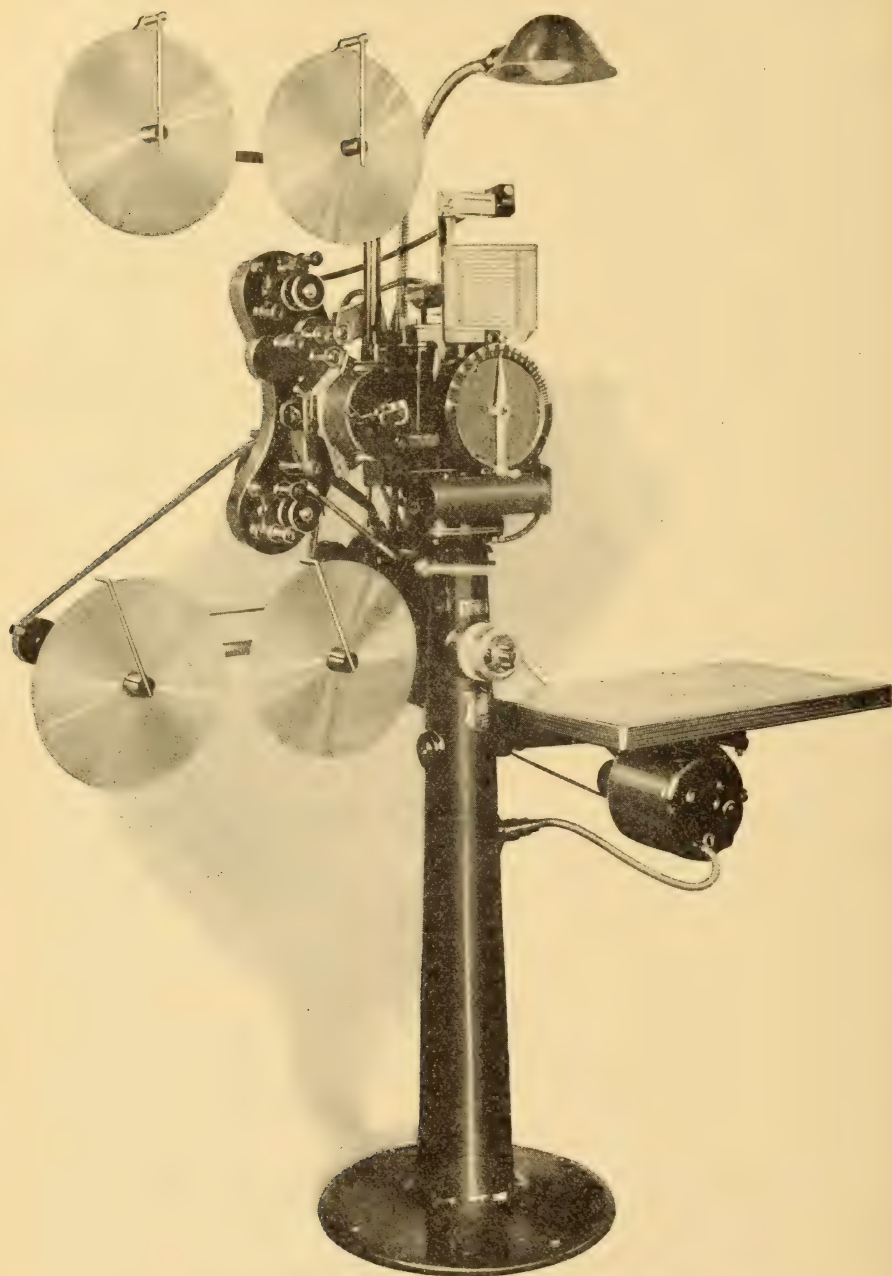


Fig. 1. Bell & Howell standard semi-automatic, continuous film printer—Model D.

permitted to accommodate with greater accuracy a greater range of shrinkage variations, without the necessity of a double standard of film perforations and which, though increasing the speed of operation, reduced to a minimum, in fact eliminated, the film wear and tear characteristic of the intermittent printer.

Shrinkage is accommodated in the continuous printer through the careful determination of the radius of the main driving sprocket, which is so calculated that the differences of arc length of the two films (the positive having the greater radius) compensate to a great extent for difference in perforation pitch; also through careful calculation of shape, size and pitch of its 64 teeth, and by providing that control of the film takes place at the printing aperture itself instead of at some distance apart from it.

Control of the film is secured by having the sprocket of the same radius as the printing aperture and a contacting surface approximately one third greater than the height of the aperture. The teeth of the sprocket engage in the perforations, (only one of them being in contact with a perforation face) and advance the films to the printing aperture. The films are brought to accurate register just before reaching the printing aperture and remain in register until printing is accomplished, with the aid of carefully balanced film tension roller weights, which maintain the film at a proper degree of tension against the contact tooth at the printing aperture sprocket, thereby providing means for correct registration and eliminating possibility of creepage or slippage between the negative and positive films.

The continuous type of printer has enjoyed a merited success during the past years due to its accuracy of performance and quantity output, and its use has become standardized in America and almost everywhere abroad in preference to the intermittent type, which was discarded except for optical printing mostly used for "trick" effect.

The advent of sound pictures has created new and more exacting requirements and again France and America have competed in the production of a printer which would represent a considerable saving in time and insure excellent quality of product. The French printer built by A. Debieu retains the intermittent movement at the picture printing aperture while the sound track is simultaneously printed in continuous motion.

The Bell & Howell Company in Chicago is offering at the present time a new printer designed by Mr. A. S. Howell, in which both sound and picture are printed simultaneously, both with continuous motion.

The Bell & Howell machine is fully automatic in operation and offers a striking departure from the heretofore mostly used method of controlling the printing light changes. A positive and instantaneous change of the light intensity without alteration of its spectral characteristic is secured for each scene and, if desired, for any portion of any scene.

The densitometric control of the printing light values is absolute for a predetermined "gamma" development and this insures at all

times the exact duplication of print densities for both the picture and the sound record.

These main features will bring about a much desirable standardization of film printing quality.

The control of the film creepage and slippage is secured through the application of the same principles which have suggested the design of the previous model of B. & H. Continuous printer with additional refinement in design and improvement in manufacture.

It would indeed be beyond the scope of this article to enter into a detailed discussion on shrinkage accommodation, and for more complete information, the reader is referred to the early transactions of the Society of Motion Picture Engineers in which the subject has been discussed by D. J. Bell; A. S. Howell; A. C. Roebuck and others.

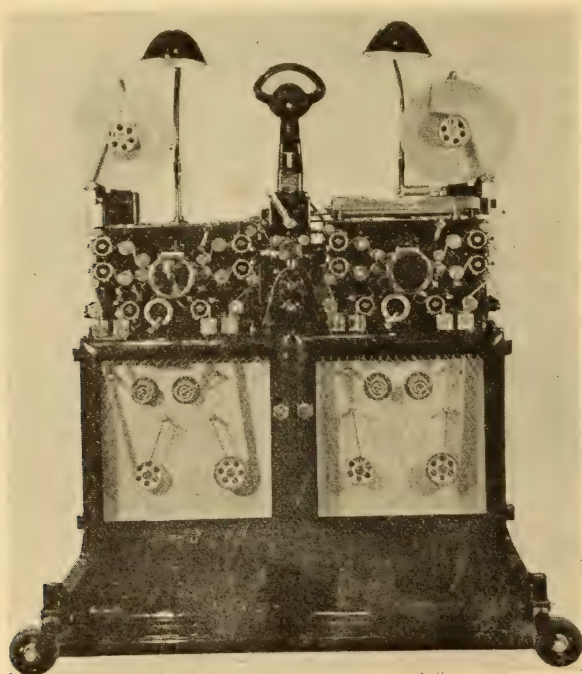


Fig. 2. Bell & Howell fully automatic standard continuous production printer for printing simultaneously both picture and sound.

It is self evident that one of the most important steps of the printing of motion picture negative films is the correct determination of the intensity of the printing light that is to be used for each negative.

In the early days this was entirely based upon the judgment and experience of an operator, who would examine the negative by transparency, arbitrarily decide upon the "printing light" to be used, check the results after printing and developing it and decide on whatever changes were necessary.

It is obvious that such a hit and miss method was inadequate and costly in time and material. So it came to be that a certain number of picture frames of each negative was printed with a light of known intensity which is, for each frame, filtered through a neutral density filter of known transmission.

This gives the operator a strip of film on which the various picture frames are printed through known light intensities which were made to correspond to every alternate step of change of light of the printer.

This is the procedure used today and "film testers" have been designed and manufactured which answer the purpose satisfactorily.

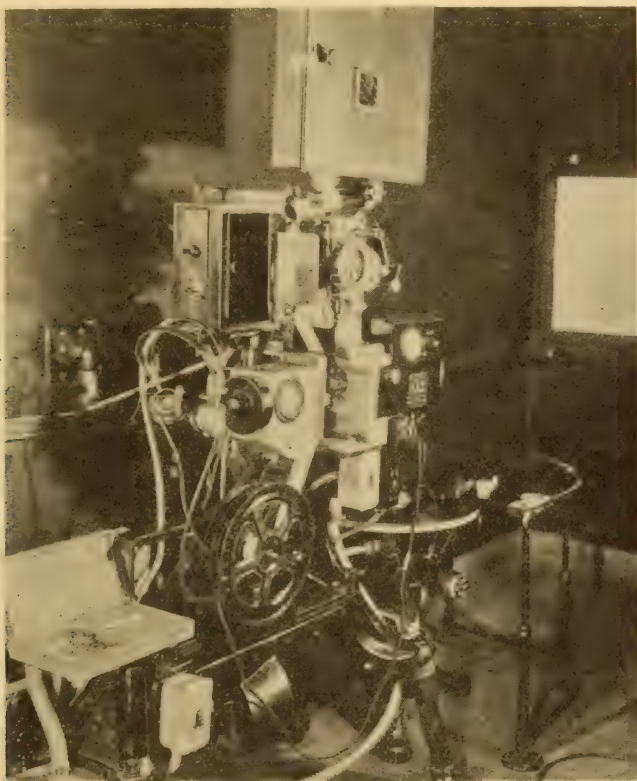


Fig. 3. A film tester.

The "Cinex" film tester is undoubtedly the most used in America and perhaps abroad, because of the efficiency of its operation resulting from careful measures taken by the manufacturer which insure a constant and uniform flux of light from the printing lamp, a perfect control of time of exposure and carefully calculated transmission of the light filtering elements.

The use of the film testing machine, though insuring a great advantage over the old hit and miss method, involves, however, visual

inspection for judging the most appropriate density at which a negative should be printed and several attempts have been made in order to eliminate the human element by devising machines which would automatically indicate the printing light to be used for any negative.

The conception of these machines is based upon the response of a photo-electric cell or a thermopile, which as it is well known varies according to the intensity of a flux of light.

Although this automatic method of printing light determination seems to hold some promises of success for the future, none of the apparatuses constructed up to the present writing has been commercially used.

Relation Between Motion Picture Laboratory Apparatuses

It is quite evident that ingenuity of design and perfection of construction of one of the machines used in the cycles of operations of motion picture processing, would be of no avail if all the machines used were not designed and constructed with the same accuracy and with a view to the close relation that exists between them.

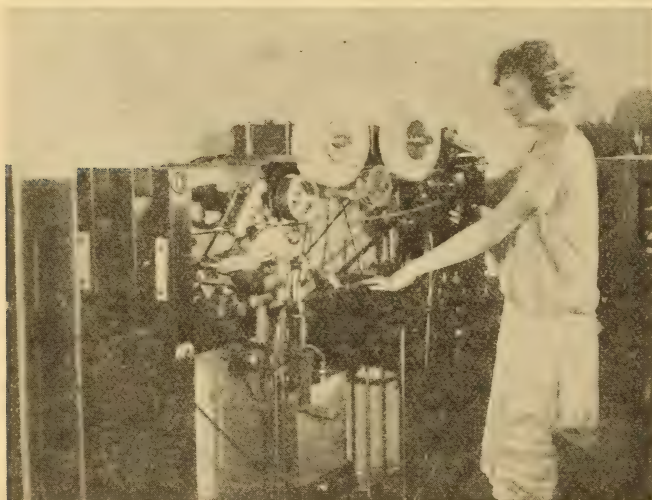


Fig. 4. Here we see a polishing machine in one of the laboratories. This is used to polish the completed film and free it from dust and scratches.

It may be said that no camera printer or projector can be better than the film perforator and no perforator, no matter how efficient it may be, can prove its practical efficiency if the other apparatuses are deficient.

The perforating of motion picture film is one of the most delicate operations that has to be performed.

The size, shape and pitch of the perforation have been determined after extensive and severe investigations and experimentations conducted with a view of determining the influence that perforations have

on the general mechanical characteristics of the film, their particular resistance to stress at both their faces and corners and many other, more or less, abstruse factors which are of the greatest importance. Perforating machines have always been rightly considered as the point of departure for mechanical perfection in motion pictures.

The Bell & Howell perforator, which is here briefly described, represents an engineering achievement which has been recognized throughout the world, and which has standardized the mechanical process of the motion picture industry.

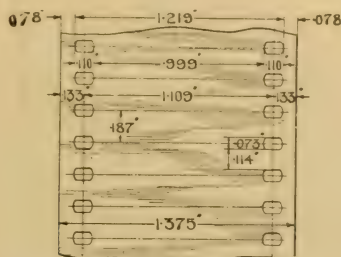


Fig. 5. Dimensions of standard film perforation gauge.

In determining the size and shape of perforation best suited for the efficient operation of the film with consideration to its maximum strength and with a view to secure accurate control throughout the various film movement mechanisms of the cameras, printers and projectors, a problem of considerable magnitude was presented, particularly when investigation revealed the fact that many perforation holes of different shapes, sizes and gauges were in use by the earlier manufacturers of film, no two of these perforations being identical and none of them proving to be theoretically or practically correct.

In computing the standard film perforating gauge, A. S. Howell gave due consideration to film shrinkage and having determined that the maximum permissible shrinkage of motion picture film is .0937 inches per foot, he concluded that a gauge length of 11.968 inches for 64 perforations would insure the necessary accuracy of perforation and at the same time make due allowance for the shrinkage of the film.

The following computation indicates the basis of the conclusion.

Assuming the outside diameter of the sprocket wheel in all standard projection machines to be $15/16$ of an inch or .9375 inch, then:

The circumference of the sprocket is 2.94525 inches.

As standard motion picture film has an average thickness of .0055 inch, the pitch diameter of the sprocket will be found to be .9375" plus .0055" or .943". Pitch circumference is $3.1416 \times .943 = 2.9625288$ ". Circular pitch equals 2.9625288 " divided by 16 (the number of teeth on the sprocket) or $.18516 +$ inch.

The standard perforation gauge being 11.968 inches for 64 perforations and the maximum allowance for shrinkage being $3/32$ inch or .09375 inch for this length of film, therefore, 11.968 inches less .09375 inch or 11.8743 inches is the average length of shrunken film measuring 64 perforations in length.

The pitch of the perforation, that is the distance from center to center of perforation is 11.8743 inches divided by 64 or .18553 inch.

Pitch of sprocket is .1852 inch.

Pitch of perforation is .1855 inch.

Thus allowing a clearance of $1\frac{1}{2}$ ten thousandths inch between sprocket tooth and film.

The drawing shows the dimensions of the Standard film negative perforation gauge.

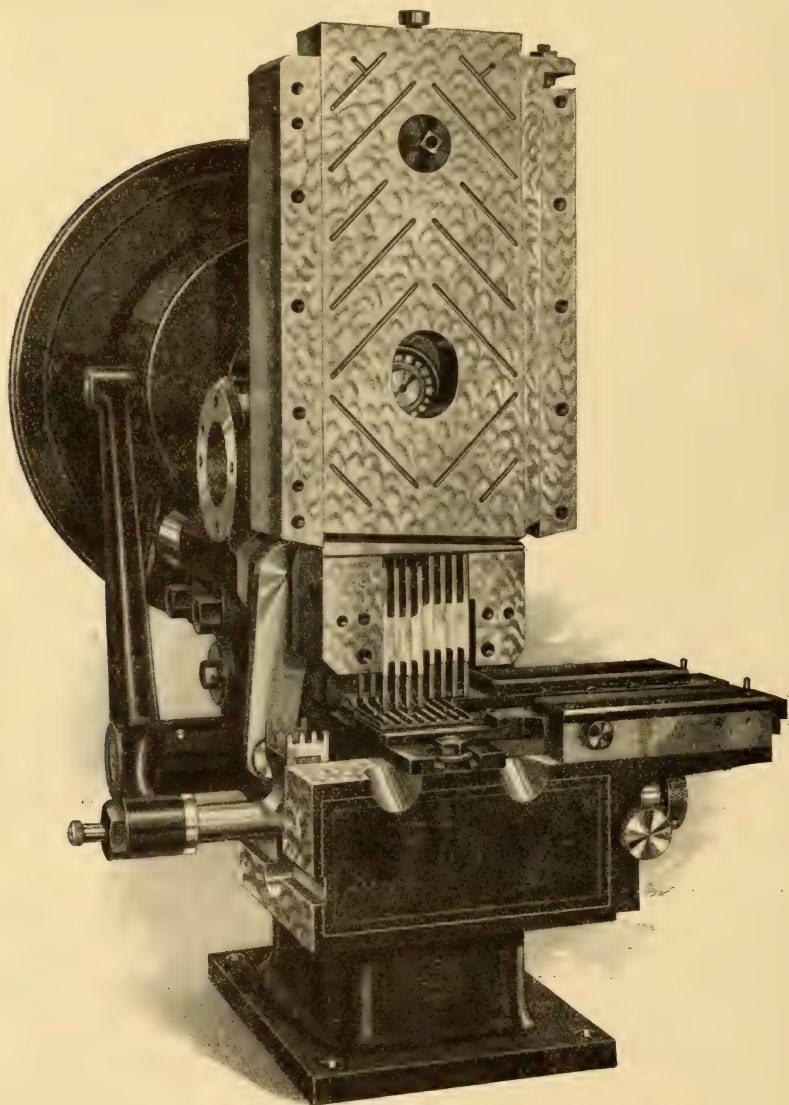


Fig. 6. Bell & Howell perforator. Detail section showing ram, gib, stripper, film guide, chute and guide rails, shuttle, punch, pilot and die.

The unperforated film is led into the cutting mechanism and locked by extremely accurate film guides. The cutting mechanism itself consists of a die and four sets of punches which enter into cutting action only after an equal number of pilots have stabilized the exact position of the film.

This punch and pilot system of perforation is one of the outstanding features of this machine, since it permits perforating a picture frame length of film with precision and uniformity within limits of one ten thousandths of an inch at each down stroke of the punches.



Fig. 7. Inspection of a B & H perforation punch.

The decision of perforating four sets of holes at each down stroke of the punches has been suggested by the fact that the mechanism of the camera, of the step printer, and of the projector, advances the film a picture length successively at each operation. It is quite obvious that the Bell & Howell method of perforating greatly facilitates precise register with the mechanisms of these other apparatuses.

It may be of interest at this point to depart somewhat from our subject and briefly review an existing undesirable condition.

It is practiced today to use a different standard of perforation for negative than for positive film.

The negative perforation has rounded sides while the positive is rectangular with rounded corners. Furthermore, the height of the positive perforation is greater than that of the negative .078" and .073" respectively while their width is equal or .110".

This undesirable condition resulted from purely commercial considerations.

At the time that the negative perforation as used today was decided upon as standard, a great number of motion picture cameras were in operation throughout the world, and a compromise of perforation shape had to be determined which would not obsolete these existing cameras.

Since positive film is handled by machinery more accessible, because of its being part of laboratory equipment, the rectangular perforation was adopted as positive standard because of the greater accuracy in registration that it permits.

It is to be hoped that the standardization of film perforation will be revised in a near future.



Fig. 8. Rack and tank developing.

Developing Machines

It was in France again that a developing machine made its first appearance. This machine was designed to develop, fix, wash and dry positive films, the processing of negatives was confined to the rack and tank system on account of the rather desultory thought that the

quality of a negative was entirely dependent upon the skill and personal judgment of the operator.

However, Panchromatic films at first, and then sound pictures, brought the realization that film processing is conducted with greater success by eliminating the human element and following principles resulting from scientific investigation.



Fig. 9. *The old-fashioned drying drum.*

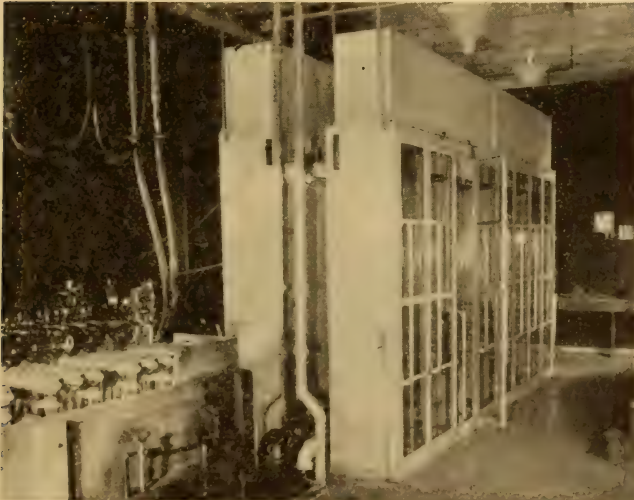


Fig. 10. *Modern, glass-enclosed drying compartment in Paramount's laboratory. Note film passing from vats of developing machine into dryer.*

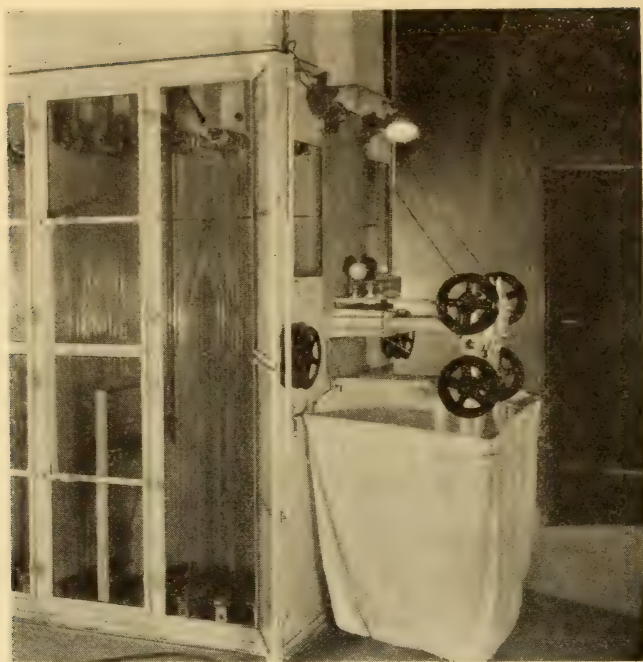


Fig. 11. Film passing from the drying compartment at Paramount laboratory onto reels for testing.



Mixing tanks for developer at M-G-M laboratory. Each tank feeds one developing machine.

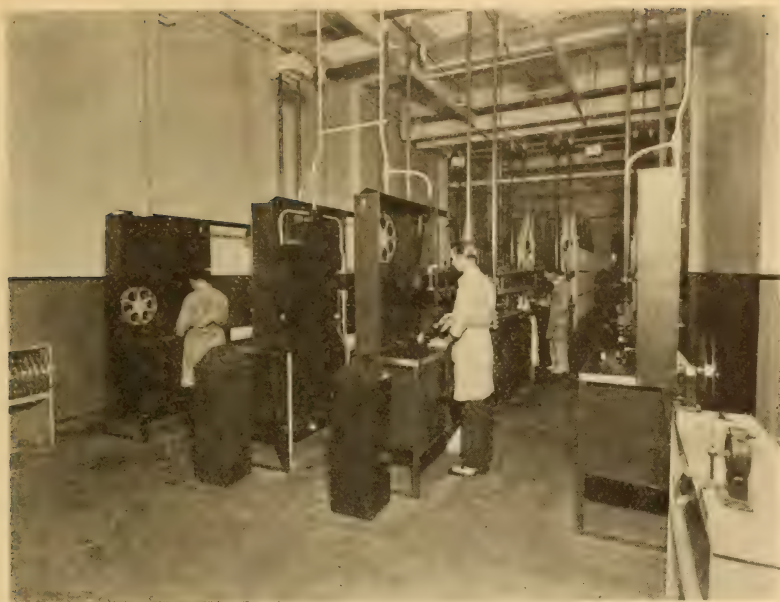


Fig. 13. General view of developing machines at M-G-M laboratories in California.

The time and temperature system practice for the development of panchromatic film because of the inadvisability of inspecting it under any light during the course of development led the way to the establishing of mechanical control of development and the adoption of sensitometric inspection.

The many types of negative developing machines which have been designed and constructed by American processing laboratories do not vary considerably among themselves nor when compared with the original positive developing machines constructed in France.

As a general principle, the film is led either vertically or horizontally by rollers into tanks containing the various solutions, and into the rinsing and washing compartments and finally in a drying and cleansing cabinet, from which it is automatically wound onto spools.

The solutions are automatically kept at constant temperature and strength and the time of development, fixing and washing is regulated through the speed at which the machine is made to run and also, in some machines, by varying the length of the film loops immersed in the developing solution.

A constant check is kept on the process of development by taking frequent "gamma" tests (every half hour or every hour of operation), thus permitting a full control of both the quality of the negatives and the densities relation between picture and sound track records.

It is quite obvious that the designing and construction of these machines have required no little research and experimentation, and their application into actual practice can be considered as one of the

most revolutionary achievements in laboratory procedure that has been realized in recent years.

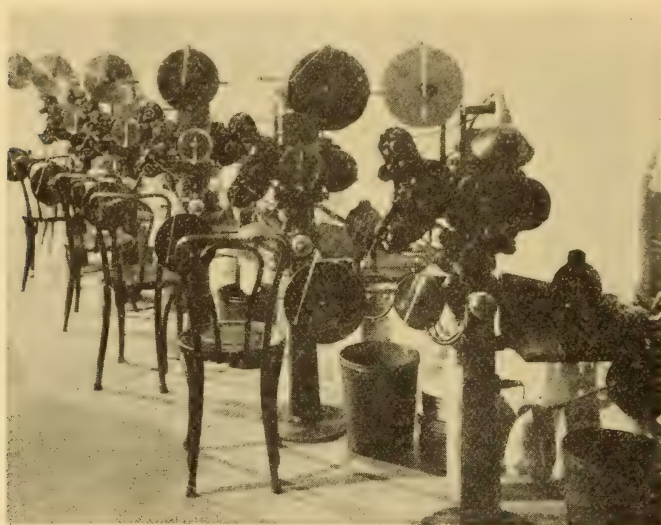


Fig. 14. A corner of Paramount's huge printing room showing six B & H printers.

Splicing of Films

The splicing of films is an operation, the importance of which has been underestimated for a long time.

Splicing in the early days was done by hand. After scraping quite roughly the emulsion at the end of the film to be patched, one would daub it with some film cement and then place the other film over it with a hit and miss attempt to match perforations. A little pressure and the job was done.

It was soon recognized, however, that this was a very poor procedure and small hand machines made their appearance, very simple apparatuses which aided somewhat in saving time, but had no pretense as to accuracy.

Again it was A. S. Howell who first gave consideration to the fact that a bad splice easily torn, entails the loss of at least two picture frames when repatching is necessary. Furthermore, a perfect alignment of the films is essential in order to avoid any sudden side motion and consequent jerking effect either in printing or projecting.

Still further consideration was given to the unsightly effect resulting from a too large and badly made splice, which is visible during projection.

In the Bell & Howell professional splicer, perfect register of the perforation is secured through the use of pilot pins carefully ground to the shape and dimensions of either the negative or the positive perforation.

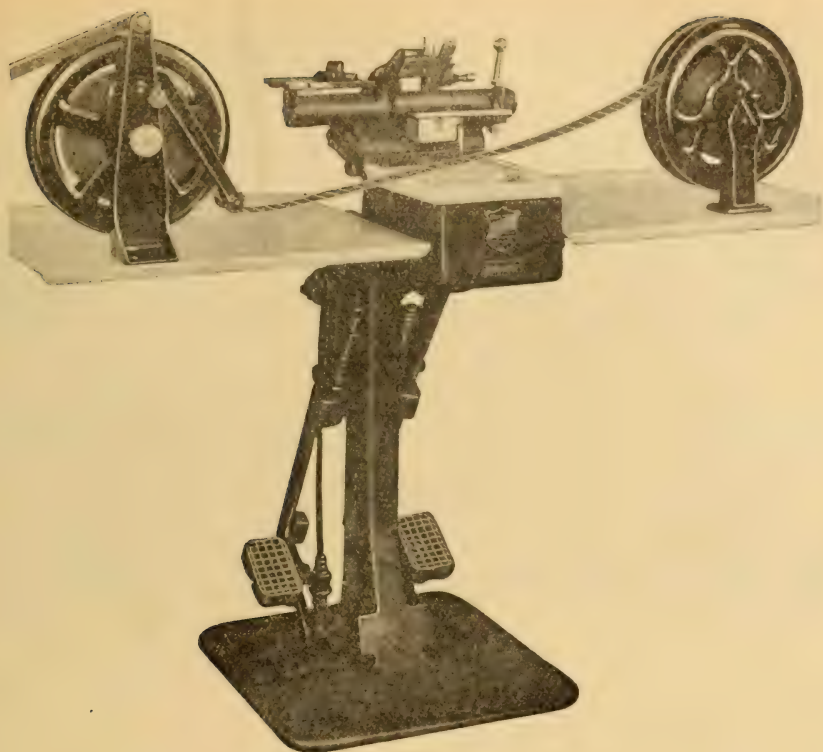


Fig. 15. Bell & Howell standard splicing machine.

The width of the splice is automatically controlled as is the proper scraping of the gelatin coating which for negatives is done with a beveled scraping blade, to eliminate excessive thickness of the splice which would prove quite disturbing for good printing.

Careful experimentation has proven that the following are the most efficient widths of splices and they have been standardized in the professional splicing machine.

Negative splice	.036"
Regular positive splice	.072"
Full hole positive splice	.156"

The illustration of the machine will give the reader a more complete idea of the principles involved in its construction than it would be possible to do in the space allotted to this brief discussion.

Mention has been made in this article only of the major apparatuses which are in common use in motion picture laboratories.

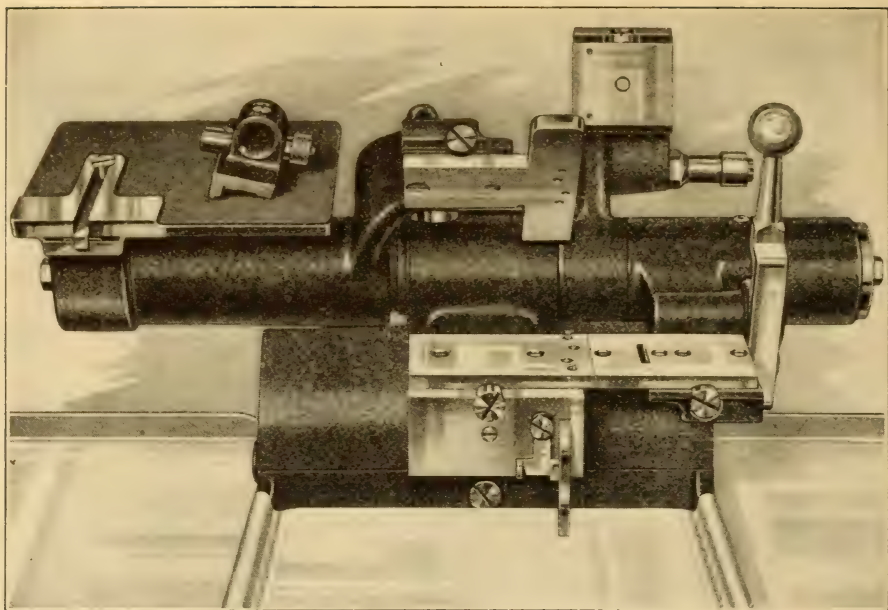


Fig. 16. *Detail of Bell & Howell standard combination splicing machine for 35 and 16 millimeter films set for splicing 35 mm. film.*



Fig. 17. *Waxing machines which wax every foot of film before it is released.*

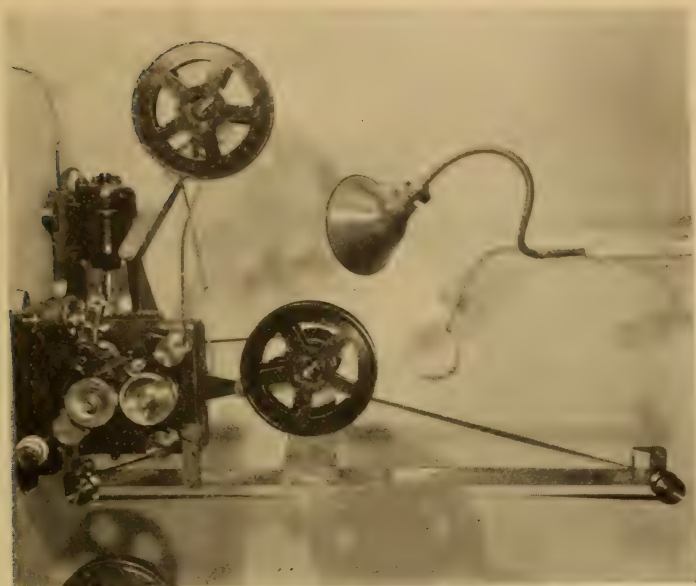


Fig. 18. Where negatives are numbered. This machine numbers the completed negatives of all pictures before prints are made for release.

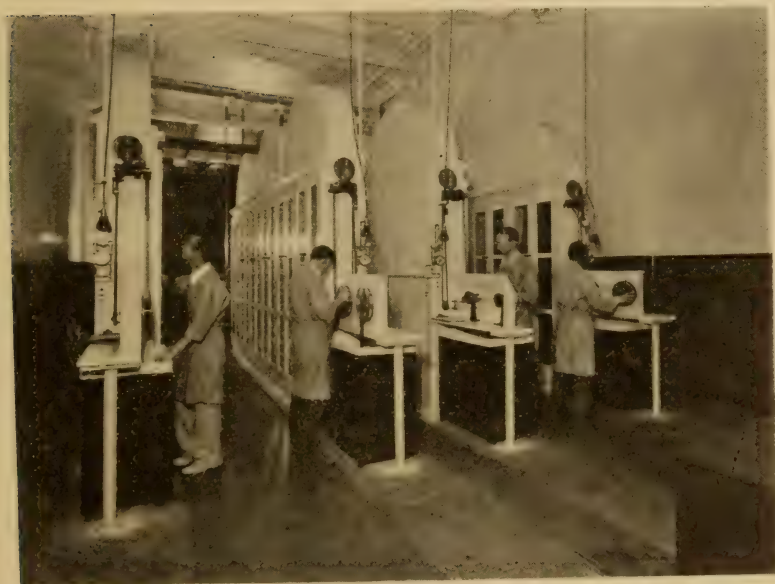


Fig. 19. View of M-G-M laboratory showing film coming from the drying racks.

The various processes involved have called for the use of other machinery, the mission of which is perhaps less spectacular, if we may use this expression, but quite important if due consideration is given to the safety and economic factors involved in laboratory procedure.

One of the most recent and interesting developments is the devising, by the Research Laboratory of the Eastman Kodak Company, of an automatic recuperation of metallic silver from the fixing baths, which not only represents considerable salvage of the precious material but also maintains the fixing solution at a constant degree of purity and efficiency.

Automatic film cleaning, waxing, rewinding machines are in constant daily use.

Every now and then the industry announces a new apparatus or an important modification of existing apparatuses used for "special process work", all of which is a truly marvelous indication of the seriousness with which our work is taken into consideration and holds untold promises for the future of this great industry.

COSTUMES AND SETS AS MEDIUMS OF EXPRESSION

Max Ree*

WITH the advent of the motion picture was born a decidedly distinct phase of theatrical expression. Its everchanging impulses demand that the banalities of yesterday be transformed to meet modern trend. We have learned along with modern conception to appreciate the truthful and convincing expression of today and have relegated to the past, the banal artificialities that made theatre "theatrical" and was followed by those who took their pretense straight! The word *theatre* conjured up the mysterious, the unreal—the theatrical. It came in the night and at the ringdown of the final curtain folded up its tent and was gone! The play was only as good as its star or leading player—while today the motion picture play's success can be credited to anyone of its contributors—the players, the director, the art-director or the cinematographer.

The world-wide reception and mass appeal of the motion picture has intensified the necessity for a greater expression of realism to which the art-director must conform. His composition must be built to withstand the analytical criticism of the neighborhood picture show patron, who, through the newsreel, the radio, rotogravure and current literature are as familiar with the interiors of a baronial castle of Gilles de Rais and the rural shades of Sixteenth Century England, as they are cognizant of what the well-dressed Eskimo will wear.

In the order of their significance—the story of course, is dominant—the players, their costumes, the settings, lighting, sound and music, with other complementary units necessary to the fabrication of convincing synthesis, all of equal importance and dependence upon the others.

The living character which the actor assumes is accented by the designer's costumes and settings which dramatize the mood of the play. Mood is intensified through light, color, sound and music.

Regardless of design, a costume can be made beautiful or ugly by the one who wears it. The incongruity of royal raiment worn slovenly makes comedy of dramatic design—and the slovenly slattern who ludicrously wears her apparel with a regal grace provokes a like effect—and regardless of the player's personality or individualism detracts from the play's conviction.

Whether for Lady Macbeth or for the extreme sophistication of the modern motion picture costume, the designer will give careful study to the characteristics and temperament of the player—first as the individual—and then the actor—fashioning the costume to meet the requisites of both, and the intensely personal choice of line, color and trifles which make for finer distinction of character, not to be

*Supervising Art Director, R-K-O Studios.

weakened with superfluities, if the full terms of the motion picture play would be transmuted, "heightened" and dramatized through a welding of atmosphere with a fusion of color and light—color supplying a greater illusion of reality and inspiration to the actor through its sensuous qualities—and lighting, either pictorial or emotional, representing a vital concomitant of the realistic motion picture play.



Mr. Ree with set model of early Osage, Oklahoma, street for "Cimarron."

A costume to be convincingly conceived must be in the same spirit as the settings—for costume itself is stage design! It also should express the locale of the story, and the actor's age, character, mood and his station in life. Sets must immediately reveal locale—and when the story allows, should reflect and complement the actor's

character, mood and station—which has been partially expressed by costume, and in order to convey their meaning more convincingly, costumes and sets must be stripped of profuse detail expressed in life, that would appear conglomerate and superfluous on the screen.



The "Osage" street completed from model.

The fact that fusion of costume and sets is of vital importance long has been recognized in the theatre where they consistently are products of the same designer, whose harmonious welding of these mediums into one unit is at once perceptible to the audience. However, in the motion picture, the dependence of costumes and sets upon each other often has been ignored—resultant in obvious incongruities. This has been due at times to lack of cooperation or difference in conception between the designer of costume and the designer of sets. Therefore, from experience I have found that a more harmonious result and greater simplification is attained when these units are executed by the same artist, who is able to visualize as a single unit, both the actor's apparel and the settings that emphasize it. The art-director who doesn't create costume for his own sets is deprived of a very important medium of expression—by which his work is brought to life—for sets are designed *only* as a part of the *visual* composition, the screen picture—actors and costumes moving against background.

Definite understanding and close cooperation must exist between the director, the cinematographer and the art-director, if the latter's conceptions would be faithfully transmuted to the public. It often



Mr. Ree with set model built to $\frac{1}{4}$ inch scale, for "Woman Between"

is difficult for these units to visualize a true perception of the ultimate product, as expressed in blueprints and perspective drawings. Models, built to scale and true in detail and color, afford opportunity to determine proportion and space requirements. The director may gain a truer perception of contemplated action and the cinematographer decide upon camera angles and lighting possibilities. The mobility of models allows for varied arrangement of detail, and compositions can be made in a fraction of the time required to revise finished sketches and drawings. This all means an appreciable saving of time and materials and eliminates many misunderstandings that might be incurred from the use of sketches. This mode of tentative set construction is not new—Michelangelo's final architectural design for St. Peters, which was first conceived in miniature, gave his co-workers a truer perception of the product in marble and stone, and since the introduction of sound pictures and their demand for authentic detail and realism, models expressive of the motion picture set have become a greater necessity.



Prison examination room for "The Case of Sergeant Grischa," expressive of cold, somber drabness. A severe, relentless and depressive atmosphere.



A provincial Russian street scene built for "The Case of Sergeant Grischa." The official looking buildings suggest authoritative severity and discipline, contrasted against the smaller, unpretentious structures. Snow intensifies this cold, harsh mood.



An atmospheric and picturesque New Orleans courtyard scene from "Dixiana," forboding drama.



*English manor dining room built for "Friends and Lovers."
A cheery, restful and rich atmosphere.*



Modern, metropolitan fashion shop from "Woman Between". A rich, unobtrusive background and frame for displaying models and gowns.



Costume from "Rio Rita". Here is feminine charm with extremity of beauty and line, for spectacular musical extravaganza.



Costume of gold cloth and leopard fur for "High Stakes", expressing vampish but refined sophistication.

Before the advent of sound, action in motion pictures was stressed to the comparative exclusion of other contributing factors—the theatre-goer was forced to rivet his eyes upon the actor in order to follow the story—but fused with *movement*, light and decoration—sound has brought a greater responsibility to the art director. Background no longer is subservient. Scenes are held longer upon the screen which gives the art director greater opportunity to impress his conceptions upon the audience, influencing them to a higher degree with authenticity and detail of the actor's pictorial surroundings. Sound has given the art director a new medium by which to express his creations—it lends suggestion of dimension and proportion to sets that are but partly expressive. The camera may reveal but a small corner of a ballroom but resounding footsteps on the hard, marble floor convey the feeling of solidity and spaciousness. Perhaps the drab interior of an antiquated hotel is suggested—its age is intensified when we hear the hollow resonance of its sagging floors and squeaky stairs! Too, sound lends atmosphere and establishes shifting



Miss Irene Dunne's costume in "Cimarron" expresses the period of 1889, as well as the age, character, mood and station of the player.



Again period, and the age, character, mood and station of the player is shown. Here the passing of time is clearly depicted and we see the modern costume, and the woman grown old.

locale—voices, the clamor of street cars, the locomotive's shriek, the honk-honk of the taxi and the roar of the elevated, the rooster's crow and the dog's bark—all designate location, long before the scene has been projected. As the blind man, to a minute degree, "sees" through sound, the audience through the same medium is able to visualize the motion picture.

The successful production means the faithful cooperation of all its factors, in the end that each one may express his contribution to the fullest extent. The critical eye of the camera is the final test of achievement and on the cinematographer rests a great responsibility. If he is both artist and technician he is able to heighten dramatic mood, and create pictorial artistry that will intensify the art director's conceptions—welding them with movement, light and color into one harmonious fusion—the screen picture.



MAKING TESTS WITH A SMALL CAMERA

With some notes on color filters.

Jackson J. Rose, A.S.C.

THE motion picture photographer faces an unusual problem when he is called upon to work outside of the studio stages. For while on the stage he knows that every factor entering into his problem is not only subject to precise control, but absolutely unvarying, in exterior work the most important of these factors—the light—becomes infinitely varying, while the need for control is greatly increased. Under modern production conditions, a company can no longer wait for just the right light conditions: the cameraman must, instead, create them. Fortunately, he has an ample variety of means at hand to do this with, for by means of the considerable range of light filters now available he can turn day into night, a clear day into a foggy one, or even increase the contrast of dull days. Furthermore, by the time a man has reached the position of a first cinematographer, and can be entrusted with the photographic responsibility for feature pictures, he has gained a vast store of experience which gives him positive knowledge of the effects of each filter or combination thereof. But, as it has already been pointed out, natural light is an infinitely varying factor. It varies not only in overall intensity, but in color and penetrating power: altitude, latitude, and a score of imperceptible atmospheric conditions will change the photographic value of light, even though the change is not visually apparent to even the expert eye. Therefore for many years cinematographers have been accustomed to make photographic tests of conditions when working on location.

Up to date, the method has been to run off two or three feet of film with the regular camera, then remove the magazine to a portable dark-room or changing-bag, and tear off and develop this test-strip. No truly satisfactory developing apparatus has been available, so this method, in addition to being wasteful of film, is also very troublesome. Yet the results, imperfect as they are, have proven eminently useful.

During the past few years, however, there have appeared several excellent still cameras which use short lengths of standard motion picture film, and for them have been developed some exceedingly practical portable developing-tanks, making a combination ideally suited for the making of such tests.

This writer has for some time used such an equipment for making tests in the field, with excellent results. For photographing the tests he selected an ordinary "Leica" still-film camera, equipped with a "Hektor" $f:2.5$ lens of 50mm. focus, and a special cine filter holder and sunshade which permits the use of any filter or combination of filters used in cinematographic work. This camera uses $5\frac{1}{2}$ foot lengths of any standard 35mm. motion picture negative film, and

makes 36 exposures on it, each exposure covering two frames. The design and construction of this camera and its optical equipment are of such high excellence that work of the best professional quality is assured, making the outfit in every way suitable for the making



Copy of a painting, photographed with the Leica camera on Eastman Super Sensitive Panchromatic film in subdued daylight. $\frac{1}{5}$ of a second, F.9 25 A Filter.

of professional tests. Furthermore, among its wide range of shutter speeds is one speed— $\frac{1}{40}$ second—which exactly corresponds to the shutter speeds of studio cameras when used at the standard talking-picture speed: therefore lens openings indicated by the tests may be used unchanged in the actual scene.

For developing the tests, the writer has found that either of the two small developing tanks made for use with this camera is satisfactory. The newer "Correx" tank is preferable, as it is smaller and simpler. The film is removed from the tiny magazine of the "Leica" in a changing-bag and placed in the tank, which is then brought into the daylight and filled with a previously prepared developing-solution—which can be an exact duplicate of the one used by the studio

laboratory. After developing for the identical time used by the regular laboratory, the developer is poured out, the film washed and fixed without being removed from the tank, and it is then ready for inspection. The entire operation takes but a few minutes, and may

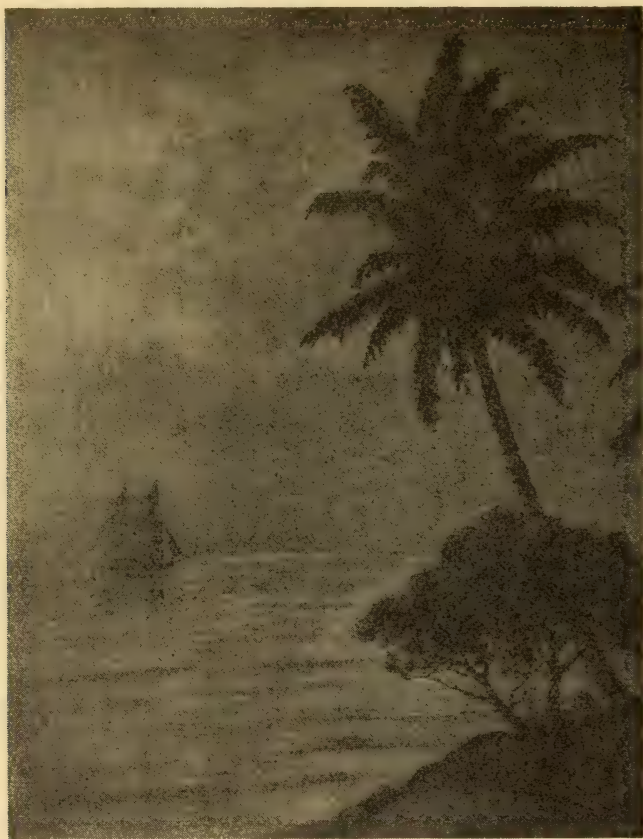


Same copy, same light as on opposite page, but 1/40' of a second, F.11, no filter.

easily be performed by an assistant cameraman while the first cinematographer continues his preparations for the shot. Then, with the conclusive evidence provided by the test—which may embrace a variety of exposures and filtering conditions, the cinematographer is ready to proceed with complete assurance that his scene will be photographically perfect.

In addition to this use for making photographic tests, these small cameras are invaluable for making stills of locations while the cinematographer and location manager are selecting locations for a picture. Recently the writer found that the picture upon which he was engaged would need a desert location; immediately he and a studio location-scout got into a car, armed with a "Leica", and within a few hours returned to the studio with nearly eighty stills, showing

several locations on different types of desert country, photographed straight, as well as with a variety of light and filter combinations. Back at the studio it was the work of only a few moments to put the film through the regular developing machine, and to have it



Copy of a painting, photographed with the Leica Camera on Eastman Super Sensitive Panchromatic film in subdued daylight. 1/20 of a second, F.9 K 3 Filter.

printed onto a strip of positive film ready to show the director, who was thereby enabled to make his choice of locations from concrete evidence of the way each would appear in the final production. This evidence is vastly more accurate and conclusive than that presented by the usual location-hunters, who return either with mere oral reports, or inconclusive stills made with a graflex, on film different from that the final picture will be made on. In case the director prefers the conventional type of stills to the positive film strips referred to, these

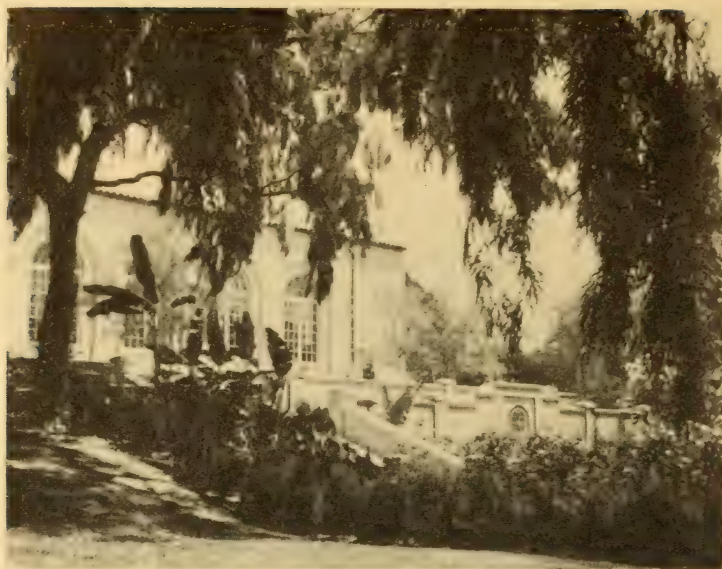
small still-film negatives can be enlarged to any size up to 14x28 inches.

Closely allied to this is another field of usefulness for still-film cameras. Few cinematographers—studio, commercial, or amateur—

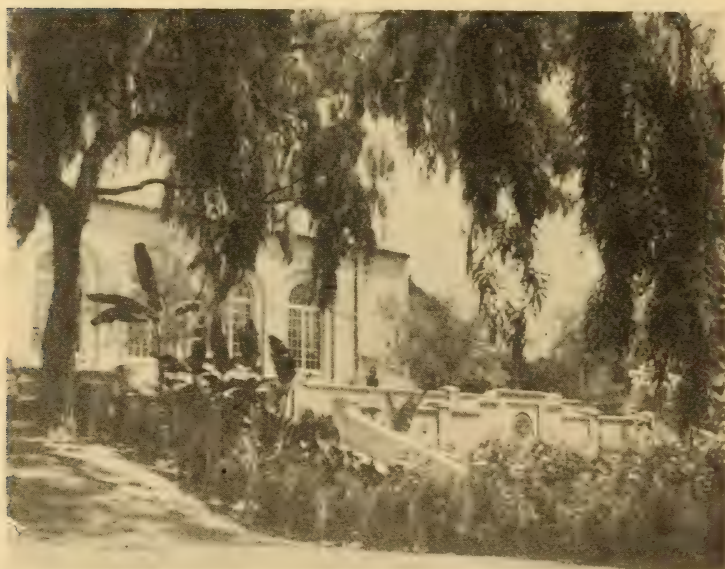


Same copy as on opposite page, same light, 1/40 sec. F.9 No. 1 Diffusion and $\frac{1}{2}$ Fog Filter.

often have the time to indulge in the private photographic experimentation that they would like to. This private research is of the most vital importance, particularly as new films and filters are constantly being introduced. These small cameras, since they will use any 35mm. film, and any professional filters, offer an excellent opportunity for this type of practical experimentation. The cost is practically negligible, and the quality is absolutely professional. In addition, the tiny negatives can be enlarged to almost any extent and



Scene in Lafayette Park, medium sunlight 10 A. M. Eastman Super Sensitive Panchromatic film. 1/60 sec. F.9 no filter.



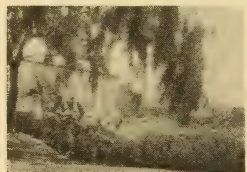
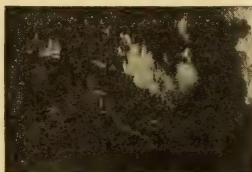
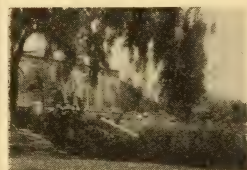
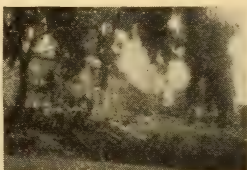
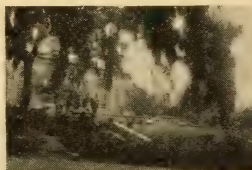
Same scene, same light, same film, 1/40 sec. F. 6.3, K 3 filter.



Same scene, same light, same film, 1/30 sec. F.6.3 K 3 filter and No. 1 Diffusion.



Same as above with No. 1½ Diffusion.

*Eastman Supersensitive Panchromatic**No. Filter**No. 21 Filter**No. 29 Filter**1/40 Sec. F.12.5**1/40 Sec. F.4.5**1/2 Sec. F.3.5**K 1+1/2 Diffusion**G Filter**25 A Filter**1/40 Sec. F.11**1/40 Sec. F.5.6**1/5 Sec. F.3.5**K 2+1/2 Diffusion**K 3+1/2 Diffusion**K 3+1 Diffusion**1/40 Sec. F.9**1/40 Sec. F.6.3**1/40 Sec. F.6.3**Medium Sunlight 10 A. M. Gray-Blue Sky.*

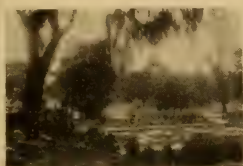
kept for reference, or used for pictorial and exhibition purposes. This work is important to studio cinematographers, but even more important to commercial and amateur workers outside of Hollywood, who have less opportunity to gather practical information on these subjects. Their work is of such a nature that an exact knowledge of the latest developments in filters and filtering is of great importance, but unfortunately they are all too frequently unequipped with that knowledge. The use of these small cameras will enable them to make the necessary experiments with the minimum outlay of time and money, and with results of the greatest precision. For their benefit the writer has compiled the following table, showing the filters most commonly used, their results, and their multiplying factors for Eastman Panchromatic Negative film, both the old Type Two and the new Super Sensitive. Space, unfortunately, does not permit the extension of this table to cover the films of other manufacturers than Eastman, but the general facts are applicable to all films, even though the results probably differ somewhat in detail, due to the differing color corrections in the different emulsions.

Eastman Supersensitive Panchromatic

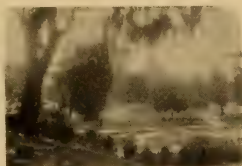
No. 1 Diffusion

No. 1 Fog

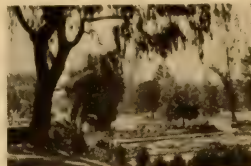
K 2 Filter



1/30 Sec. F.12.5



1/20 Sec. F.12.5



1/20 Sec. F.11

No. 21 Filter

G Filter

K 3 Filter



1/30 Sec. F.4.5



1/30 Sec. F.6.3



1/20 Sec. F.9

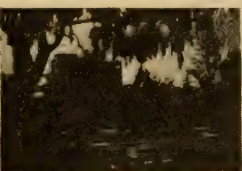
25 A Filter

29 F Filter

25 A + 56 B



1/20 Sec. F. 3.5



1/5 Sec. F.3.5



1 Sec. F.3.5

Medium Sunlight 9 A. M. Grau-Blue Sky.

WRITTEN COLOR FILTERS

Filter No.	Name	Filter Factor Super Sensitive	Filter Factor Type Two	USE
6	K 1	1.8	2.2	Cutting slight haze on exteriors; for slight color-correction; to slightly increase contrast of faces on dull days.
8	K 2	2.1	2.8	For medium color correction and cloud scenes. Most popular filter used.
9	K 3	2.4	3.2	For full color correction. Best filter for general exterior work. Useful to increase contrast in flat daylight.
15	G	2.6	3.7	For maximum contrast in flat light. Useful for brilliant sunsets. Will turn blue sky grey.
21	21	4	8	Used principally for general sunset effects, and to render yellow and orange very light. This filter is gaining popularity.
25	A	6	12	Tricolor red filter. Used mostly for overcorrection of blue sky, which it turns a dark grey, and for making night scenes by day.
29	F	12	25	Extra heavy red filter. For extreme contrast; makes blue sky photograph black. For night effects by daylight, but can only be used in strong sunlight.
49	C	8	10	Tricolor blue filter. Used for soft effects in blue light, and to soften sky from harsh white to soft grey.
56	B	8	10	Tricolor green filter. Makes foliage appear very light; a good general soft filter for landscapes. Also used with the 25 A for making night scenes by day.

NATURAL DENSITY FILTERS

Filter No.	Name	Filter Factor Super Sensitive	Filter Factor For Type Two	USE
	25 %	2	2	Used to slightly soften contrasty scenes.
	50 %	3	3	Most popular of the Neutral Density filters. Used to soften harsh highlights or glaring skies.
	75 %	4½	4½	Used to modify harsh contrasts, and in combination with fog filters, to produce general fog effects.
	100 %	8	8	To soften extreme harshness, such as sunsets, back-light on water, strong sunlight on white objects, as cement walks, etc.

SCHEIBE DIFFUSION FILTERS

Filter No.	Name	Filter Factor Super Sensitive	Filter Factor For Type Two	USE
	½	0	0	For slight diffusion in long-shots. When used with 25 % Neutral Density, gives very beautiful soft effect upon foliage and water scenes.
	1	½	½	For medium diffusion on light objects; gives the slightly fuzzy softness popular with all cameramen. Useful in making still enlargements.
	1½	¾	¾	For extreme diffusion of long-shots. Used mostly, however, for close-ups; eliminates most of the harsh lines on faces.

SCHEIBE FOG FILTERS

Filter No.	Name	Filter Factor Super Sensitive	Filter Factor For Type Two	USE
	½	¼	¼	For slightly hazy effects on both exteriors and interiors.
	1	½	½	Used with 50 % and 75 % Neutral Density filters for fog effects. Used alone makes good effects on water shots.
	1½	¾	¾	For extreme fog effects or ghostly sequences. Principally used on water scenes with 50 % Neutral Density filter.

The 49 C filter may be used as a viewing filter when using Orthochromatic film.

The Wratten 90 filter serves as a viewing screen for Panchromatic film, and when used together with any color filter will indicate visually the color rendition that that filter will give. *The 90 must only be used for viewing purposes.*

In using yellow or green filters (K-1, K-2, K-3, B) the best results will follow a very slight underexposure.

It is always best to overexpose slightly when using contrast filters such as the G, 21, A and F.

A slight overexposure with all neutral density filters will give softer results. All neutral density filters may be used in combination with fog filters, depending on the results desired.

It is quite as important to shade the filter from direct sunlight as it is to shade the lens.

When not in use, all filters should be protected from moisture or direct sunlight. Moisture will soften the cement, and spoil the filters, while sunlight will fade certain of the pigments.

THE ELEMENTS OF LIGHTING

William Stull, A.S.C.

IT IS unfortunate that the average amateur cinematographer (whether he be a user of 16 mm., 35 mm. or 9.5 mm. apparatus), all too frequently labors under the misconception that cinematography by artificial light is something tremendously difficult, and attainable only by professionals, or by a few rare advanced amateurs. Nothing farther removed from the truth could be imagined: indoor cinematography is easy—particularly since the introduction of the new "Fast" emulsions on 16 mm. and 35 mm. stocks. Furthermore, it is undoubtedly one of the most interesting fields open to the non-professional cinematographer. Its possibilities, both as to artistry and subject-matter, are unlimited, and its requirements are very simple.

In the matter of equipment, the chief requirements are a good camera and tripod, and a few lighting units. The camera should be fitted with a reasonably fast lens—the faster the better, for although with the new "Special" and "Super Sensitive" films now available, a great deal can be done with an $f:3.5$ lens, the faster objectives, working at speeds like $f:1.8$ or $f:1.5$, permit either the use of less light, or, with the same amount of light, the covering of larger areas. With fast lenses and the new fast film, the ordinary house-lighting fixtures, plus ordinary 100 or 200 Watt bulbs, become excellent lighting units for photographic use. In addition, the regular photographic lights so long available for amateur use, become even more useful. Naturally, they control the light much more efficiently than do ordinary bridge-lamps, and, too, they can now be used with various diffusing media, which were formerly all but tabu with the old film.

The use of these lighting units was imperative with the slower emulsions, and now, with the faster films, even though they are not absolutely mandatory, they are still exceedingly useful because, unlike the house-lighting units, which are designed to give a general illumination, they are designed strictly for the purpose of giving a relatively concentrated light, and specifically for photography. Getting the best results in lighting depends upon being able to control the light completely, not only as to direction, but also as to the quality and the degree of dispersion; therefore, since these photographic lighting units are made to do just this, they form a distinctly worthwhile investment.

In choosing such equipment, the amateur has a great variety offered him. In the first place, he may choose between the carbon arc and the incandescent bulb as the source of the light. In the days before the introduction of Panchromatic film, the arc was by all odds the best, as it was far more intense; furthermore, there was very little incandescent equipment available. But Panchromatic film brought with it the incandescent light, for both the professional and the amateur, as it was far more sensitive to the yellowish rays of the "inkie" than was the old, ortho film. And now that the new, super-pan-

chromatic emulsions are available to the amateur, with their extreme sensitivity to incandescent light, there is very little choice, as the greatest benefits of the new film are only gained by using the incandescent lamp. For Kodacolor, on the other hand, the arc is still superior, as the warmer light of the inkie tends to give an unpleasantly ruddy hue to the picture.

No matter which type of film is used, no unduly great number of lighting units need be used. A single unit, used intelligently in connection with fast film and ordinary house-lights, will do a great deal. Two identical units will extend the range further, and three units are all that one should ever need. At times, a small spotlight (either arc or incandescent) may be very useful; but it is by no means a necessity. Much more necessary are several simple accessories. The first of these is the diffuser. Studio cinematographers have a most amazing variety of these; but for amateur work, a single type is sufficient. This is made by stretching tracing-cloth or muslin over a simple frame of wood or wire, which may be fastened in front of the lighting fixtures. This softens the light, making more natural effects possible. Another very useful accessory is an extension-cable terminating in a junction-box with four or more outlets, into which the individual lamp-cables may be plugged. This allows much greater freedom in the use of several lamps, and is a great time-saver. Still another useful accessory is an assortment of bulbs for your lights, of different wattage, and of different shades—clear, frosted, amber, etc. And, if one is making pictures away from home, a pocket-full of fuses is essential, for most house circuits are usually fitted with 10 or 15 Ampere fuses, while the 1500 to 2000 Watts usually consumed by the three or four lights used for amateur work requires 25 or 30 Ampere fuses.

As regards mental equipment, the only requirements are a knowledge of the basic principles of lighting, and—experience.

In lighting any subject for photography, two requirements must always be met: *first*, the subject must receive sufficient light to permit an exposure; *second*, the light must fall upon that subject in such a way as to produce the maximum effect of depth and roundness.

The first requirement is simple enough, and very easily fulfilled, now that fast lenses and fast film are available.

The second, too, is essentially simple, but it leads on to as great a degree of intricacy as the user's ability and equipment may permit.

In so far as the amateur cinematographer is concerned, there are two salient types of lighting: that applied to the illumination of rooms, and that dealing with the lighting of people. Obviously, they are more than a little interrelated, but they may be treated as separate problems, bearing in mind, however, that in actual practice they are almost invariably connected.

In lighting a room, we must usually deal in broad effects. The best thing to do is to consider the possibilities offered by the lighting fixtures of the room—chandeliers, wall-brackets, reading and table-lamps, etc. Then, between the amazing sensitivity of the new Fast Film, and the use of only moderately large bulbs (100 to 250 Watts) in these fixtures, we can usually contrive to get sufficient illumination

to permit satisfactory photography. If more light is needed anywhere, one or more of the regular photographic lighting units can be used, usually with diffusers. It is a mistake, however, to believe that a room must be completely bathed in light for photography. Quite the reverse! If we merely flood the room with light, we will have a flat, unpleasing picture. We must not forget that we want to secure the maximum illusion of depth and actuality in our picture; to do this, we must create the illusion with our lighting. There are so many little tricks which can be employed to do this that the limited space available here permits only hinting at a few: but, after all, the best text-book on lighting is the screen of your neighborhood theatre, where you can study the work of the greatest masters of cinematographic lighting at your leisure. One of the most obvious methods of fostering this illusion of depth is contrasting the different planes; silhouetting the objects in the foreground against a more brilliantly-lighted middle-ground, which, in turn, may be set off by a more softly-illuminated background. On the other hand, if the interest centres in the foreground, that is the plane which should be most prominently lit; in any case, a good rule to follow is to make that part of the picture in which the interest centers—where the main action is—the keynote of your lighting scheme. The rest can take care of itself.

Another important thing to remember is that in a long-shot particularly, you will probably include some lighting fixture from which the illumination of the room can be made to *appear* to come. This does not by any means mean that *all* the light must come from that source, or even appear to; but it does mean that that source should be considered in the lighting of the whole scene. It would be most unnatural, for instance, if in a scene which prominently included a large lamp at the left-hand side of the picture (and which was obviously lighted), the majority of the light came from the right, at which there was no apparent source of light.

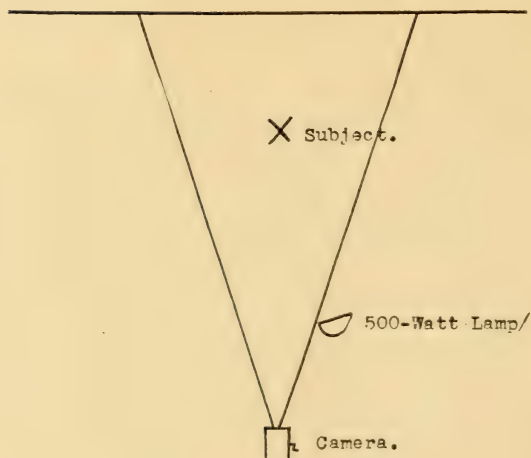
Curving surfaces, such as pillars, and table and chair-legs, vases, etc., can be made to seem round by the use of judiciously placed high-lights. So, too, can people, and furniture be made to seem more substantial by the use of back-lighting.

When we consider the lighting of people, on the other hand, either in medium-shots or close-ups, we face a different problem. Here, instead of striving for bold effects, we must seek delicate gradations. It becomes, in fact, more a matter of individual portraiture than of merely illuminating a certain area for photography. We face the same problem, however, in that we must so light these people as to give the illusion of roundness and reality when the picture is projected upon the flat surface of the screen. This is done by securing the proper play of light and shade in delicate gradations upon their faces and forms. And here is where both the fascination and the complexity of lighting enter. The relative positions of lights and subject have everything to do with the result finally reaching the screen, for each change in the position of any of them will naturally alter this play of light and shade upon the subject—and it is that play of light

and shade that creates the illusion of actuality for which we are striving. Furthermore, no two people can be lighted in exactly the same manner; each new subject is a new and interesting problem, as well. Form, features, coloring, and costume all enter into the problem; it is the photographer's duty to know how to deal with each in such a way as to master his problem of making the best possible picture.



Fig. 1. *Plain front light.*

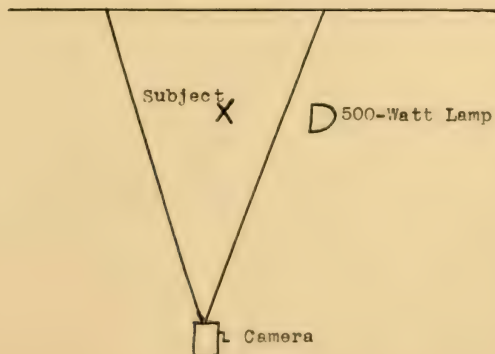


To do this, he must, first of all, know the general effects of each style of lighting—of each basic position of the lights. And like anything else, lighting is built up from relatively simple ingredients. The simplest, of course, are the effects secured with but a single light-source.

The first and simplest of these is the plain "front light", shown in Figure 1. This is adequate enough from the purely mechanical viewpoint, but it gives a decidedly flat result—a mere mechanical reproduction of the subject, without either character or illusion of roundness. It is not too bad if the exposure is perfect, but if the pic-



Fig. 2. Plain side light.

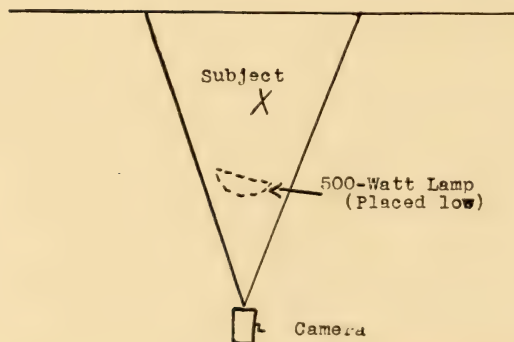


ture is overexposed even a trifle (especially on reversal film), the result is most unpleasant. As the diagram shows, the illustration was made by placing a single 500-Watt lamp (in this case, a Model B Eastman "Kodalite") directly in front of the subject, just out of the camera line, and with the lamp at about the height of the subject's face.

The second basic lighting is the plain side light, shown in Figure 2. This gives a considerably greater effect of roundness and depth, but pays for it with the sacrifice of all detail in the shadow side of the



Fig. 3. Low front light.



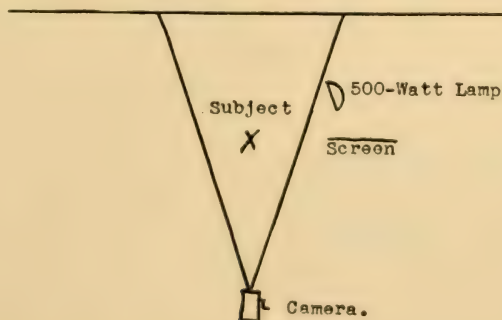
picture. It was produced by placing the light directly to the side of the sitter, and at the same level as before.

Figure 3 shows another basic lighting, a low front light. In this case the light was placed directly in front of the subject, and as low as possible, with the beam, of course, directed upwards. It is slightly less flat than a plain front light, but gives such an unnatural effect as to be of little practical use. The illustration does not show a true under-lighting, which gives an even more unnatural effect, as such a set-up can rarely be used in amateur work.

The same restrictions apply to the true top-light, which, though at times useful for purely dramatic reasons, is generally impractical for



Fig. 4. *High side light, slightly behind subject.*

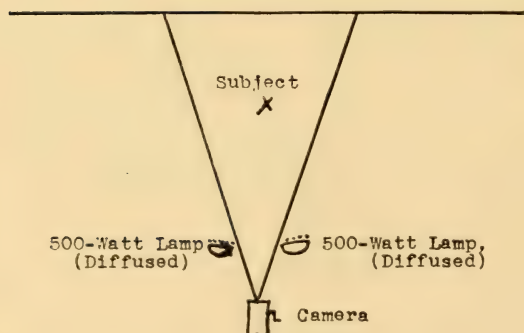


obvious reasons, as well as for the fact that it gives a very unpleasant effect. Figure 4 shows a development of the top-lighting, in which the light was placed above the subject, at the side, and well to the rear. It results in somewhat better modelling, but is in the main too unpleasing to be used alone, although, as will be seen later, it is quite useful in combination with some form of front light.

The true back-light, as used by the professional, is likewise generally beyond the scope of the amateur. In the studio, the back-lighting equipment can be placed on the top of the set, out of the range of the camera; but this sort of arrangement is generally beyond the



Fig. 5. *Incorrectly balanced front light, two sources; flat.*

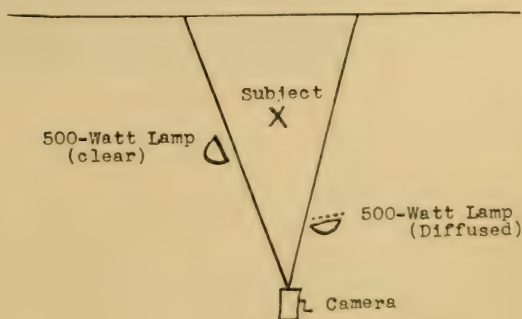


range of the amateur's facilities. In its place, the back-side light, shown in Figure 4, is best used. Except for special, dramatic effects, of course the back-light can never be used alone.

When using two light-sources, the important thing to remember is to balance the light properly. This does not mean, as one might expect, to keep both sides illuminated identically; quite the reverse. It means keeping the illumination from the two sources in such a relation that there will be a pleasing play of light and shade on the subject. In lighting, as in everything else, there must be two sides to the picture; in this case, a shadow side and a high-light side. The difference in the intensity of illumination falling upon these two sides,



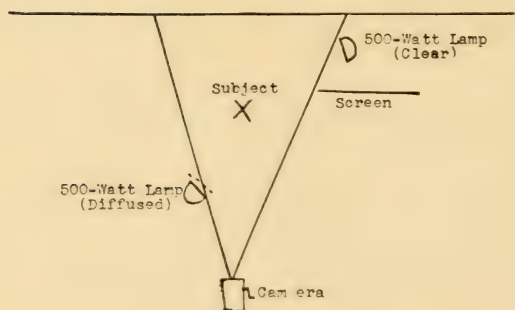
Fig. 6. Properly balanced front light, two sources.



together, often, with the difference in the angles from which the light comes, determines the play of light and shade, and, in turn, the modelling—the effect of relief, or roundness—in the final picture. A good rule to go by is to have the light on the shadow side but half as intense as that on the high-light side. There are many ways to do this. The simplest is to have the light illuminating the bright side nearer to the subject than the one illuminating the shadow side. Another method, of course, is to use bulbs of higher wattage on the bright side. Still another way is to use a diffuser on the shaded side. But in any event, do not make the mistake of illuminating both sides identically, as that gives a very flat picture, as shown in Figure 5,



Fig. 7. *Back-lighting. Back-light too "hot".*

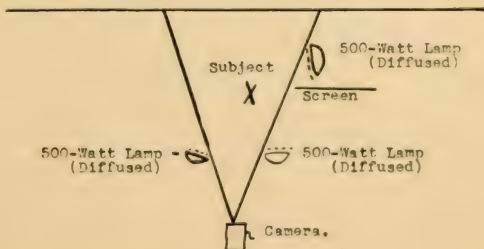


which was lighted by two 500-Watt lamps, each fitted with a diffusing-screen of tracing-cloth, and placed as shown in the diagram, in identical positions on either side of the camera-line. Figure 6, on the other hand, shows a properly balanced front lighting. The right-hand light, illuminating the shadow side of the subject, was in the same position as in Figure 5, and is diffused. The left-hand light, illuminating the bright side, was moved much closer in, and a bit to the side, while the diffuser was removed. This combination results in greatly improved naturalness in the picture, and a somewhat better illusion of depth.

But even this does not give the maximum illusion of roundness. The next step is back-lighting. The amateur worker is rarely in a position to use a true back-light, but he can often use a back-side light, which does almost as well in most cases. Figure 7 shows this.



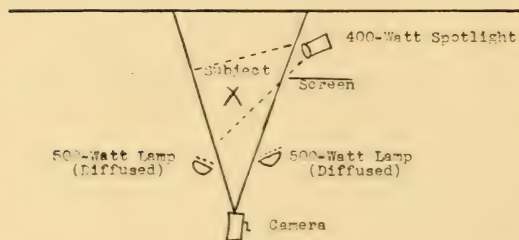
Fig. 8. *Back-lighting. Diffused back-light gives a better result.*



The front light is from a single 500-Watt lamp, placed almost directly in front of the subject, and just to the left of the camera-line. It is not diffused. The back light is from another 500-Watt lamp, placed well behind the subject, and far enough to the side to be out of the picture. Its rays are directed forward onto the subject, and shielded from the lens of the camera by a screen, as shown in the diagram. It can readily be seen how greatly this back-light improves the illusion of roundness in both the face and form of the subject, the back light, however, is in this case a trifle too intense—too “hot”, in the studio idiom—and could well be diffused somewhat. Figure 8 shows a more diffused back light, with a diffused front light as well. The front light set-up is practically the same as shown in Figure 5,



Fig. 9. Back-lighting with a spotlight; flooded out too much.

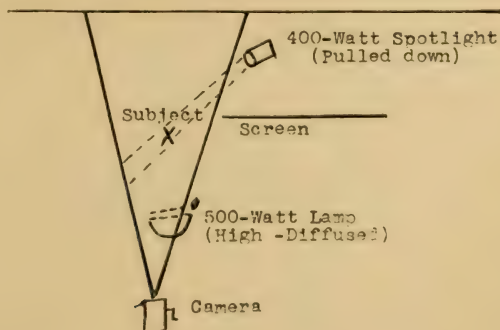


save that the lamps are slightly closer to the subject, and, necessarily, a bit farther apart. Both are diffused, as is the back light.

The spotlight is at times a very handy lighting tool, as it can not only be diffused, but focused; it can be brought down to a fairly small, concentrated circle, or "flooded out" to a considerably larger and less intense one. This is frequently very useful in backlighting. Figure 9 shows a 400-Watt spotlight used for backlighting, flooded out full. The front-light is the same as in Figure 8. In figure 10, the spotlight is concentrated—"pulled down", to use the studio phrase—and the front-light is from a single, diffused 500-Watt lamp,



Fig. 10. Back-lighting with a spotlight: properly concentrated on subject.

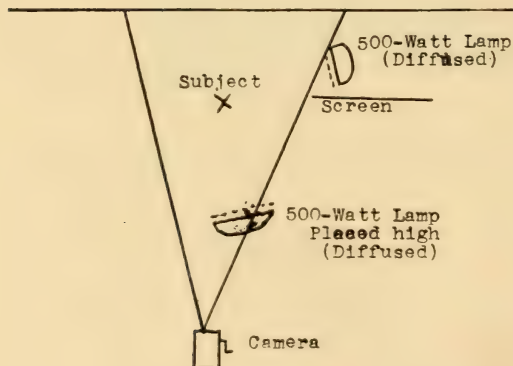


raised fairly high, and placed almost on the center-line of the picture, resulting in rather better modelling of the lower part of the subject's face. Figure 11 shows the same sort of set-up, but with the spotlight replaced by an ordinary Kodalite, diffused.

The best results, of course, are obtained through the combination of well-balanced front-light and back-light. This is shown in Figure 12. The front-light is the same, well-balanced arrangement used in Figure 6. The back-light is from a spotlight, pulled down and concentrated on the subject's head.



Fig. 11. *Soft, natural effects should always be striven for.*

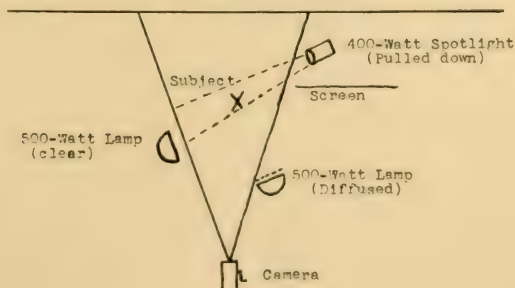


Special lightings, of types ordinarily entirely unsuitable for general work, can often be used very advantageously to secure special dramatic effects. One of these is shown in Figure 13, where a single spotlight was used to secure the effect of an ordinary electric hand-torch, as is often required in mystery stories. Figures 14 and 15 show another effect-lighting, Figure 14 having been made with a flooded spot for back-light, and a diffused and distant front-light. Figure 15 is identical, except that the front-light is extinguished, leaving only the spectacular effect shown.

Aside from these special effects, however, the chief end and aim of all lighting should be absolute naturalness. Photography which calls



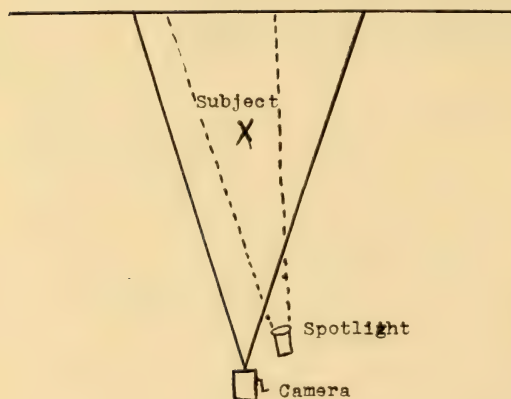
Fig. 12. *Properly balanced front lights and spot back-light.*



attention to itself is never good; no more is self-assertive lighting. Every picture, professional or amateur, has its definite story to tell. It may be a sweeping epic like "Cimarron," or it may be merely the homely record of baby's bath, or an evening's bridge-session—but the story is there, whether we recognize it as such, or not, and it is the duty of the photographer to recognize it, and to so execute his work



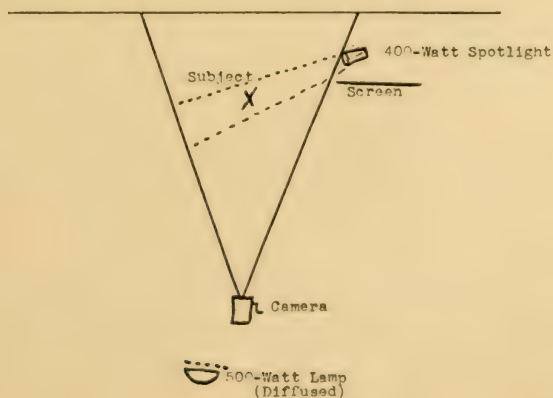
Fig. 13. A special dramatic effect secured with a single spotlight.



that neither photography, lighting, nor any other technical detail interferes with the telling of that story. He can—and must—compose and light his pictures attractively, but never must he allow himself to let these details distract his audience from its enjoyment of the story. That is the basic law of all cinematography, and it may be observed in the work of all great cinematographers the world over. And it is greatly to the amateur's advantage to observe the work of the professional—to remember that the greatest school of cinema-



Fig. 14. *An interesting low-key lighting for dramatic effects.*



tography in the world is the school of experience, and, next to that, his neighborhood theatre. There he can study the lighting, filtering, and general camera technique of the greatest cinematographers of the world. Then, knowing the basic principles of cinematography and lighting, he can go to his own studio—his home—and adapt the lessons learned from his professional fellows to his own needs, and, if he has learned his lessons well, constantly produce better pictures for his own enjoyment.

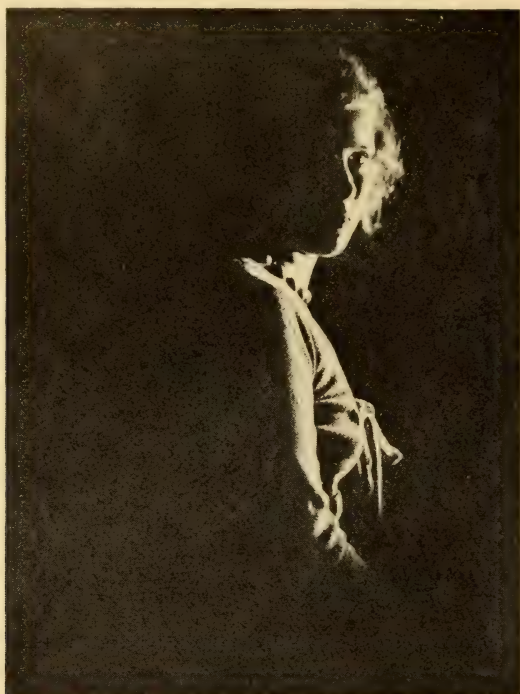
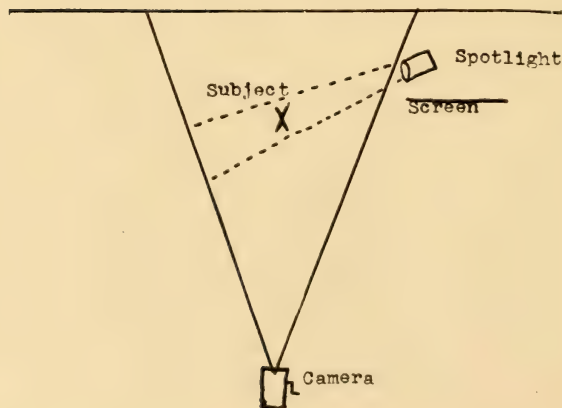


Fig. 15. *An elaboration of Fig. 14; no front light used.*



(Footnote — The lightings used in the illustrations have been somewhat exaggerated in order to make the methods used more easily understood. In practice the reader should strive for softer and less obvious effects, as lighting must always be merely a means to an end—never an end in itself.)

A PARALLEL OF TECHNICAL VALUES BETWEEN 35 AND 16 MILLIMETER FILMS

*J. A. Dubray and R. F. Mitchell**

WHEN first introduced, 16-mm film was essentially confined to amateur cinematography. However, the last few years have shown an interesting and constant increase of the use of 16 millimeter film in more academic work than that usually done by amateurs.

The Industrial, Scientific and Educational fields have become aware of the opportunities that 16 millimeter films offer for producing and exhibiting at a moderate cost, motion pictures of a quality which favorably compare with the 35 millimeter professional standard.

Industrial organizations use 16 millimeter films for keeping records of manufacturing processes, for instructing their employees on established manufacturing, packing, shipping, safety processes and measures adopted within the organization, and for broadcasting to the buyer or the public at large, the characteristics and qualities of the product they manufacture.

In the scientific world, 16 millimeter films have proven invaluable to the laboratory researcher, and have found a prominent place in the surgical and medical clinics.

16 millimeter films have entered the classroom, the large as well as the small auditoriums, and their use is rapidly increasing and receiving official sanction.

These phases of practical usefulness of motion pictures have been making extremely rapid strides and 16 millimeter films are often preferred to the professional 35 millimeter, for economic as well as technical reasons.

It happens, however, quite often that a prospective user of motion pictures, or even one perfectly conversant with 35 millimeter films, is quite in doubt as to which type of film he should use for a particular purpose, and the question which is perhaps most often asked by semi-professional cinematographers is "When and why should I use 35 millimeter films in preference to 16 millimeter and vice versa".

We will attempt to answer this question with special reference to simple technical considerations in preference to the economical factor involved and which is obviously in favor of 16 millimeter with regard to both equipment and operating costs.

In order to logically follow the various factors involved in the matter, we will consider, under different headings, the methods of handling the various operating phases which contribute to make a finished motion picture:

Equipment

Perfection of design and manufacture of machinery and equipment constructed for handling motion picture films is of prime importance irrespective of the type and size of the film itself.

* Technical Service Dept.—Bell and Howell Co., Chicago.

Motion picture film, be it of 35 millimeter or 16 millimeter size, is, during projection, subjected to a great magnification and therefore any mechanical imperfection in the construction of the machines through which it is made to pass (perforator, printer, camera or projector) is many folds multiple upon the screen.

The average magnification to which 35 millimeter film is subjected during projection on a theatre screen is approximately from 350 to 400 times diametrically.

An error of registration of subsequent picture frames of one thousandth of an inch results in a quivering of the screen image for an extent nearing half an inch, which is very noticeable under normal conditions and cannot be tolerated in cases where the unsteadiness of the projected image is made more apparent by means of comparison. Titles, for example, demand great accuracy of register because of easy comparison with the stationary border of the screen and obviously any picture which has involved a double or multiple exposure would be utterly spoiled if the records at different times were not registered with the most exact accuracy.

Under all conditions, an error of register of one hundredth of an inch would result in a quivering of the projected image to the extent of four inches, which is absolutely intolerable.

It is true that the magnification usually exacted from 16 millimeter film is not as great as that to which 35 millimeter films are subjected, but it is also true that the distance from which 16 millimeter projection is seen is usually less than that of 35 millimeter and therefore, errors of registration and unsteadiness of the image are as visible and as disturbing.

Perfect film registration involves mechanical problems of difficult solution, mainly because of the shrinkage characteristic of the film. Both 35 millimeter and 16 millimeter films consist of a thin layer of gelatin which serves as a binder, so to speak, for the extremely minute particles of a silver compound, (which is the light sensitive material) which is in turn coated over a celluloid support, called the base.

This base is an unstable material. That is to say, it is subject to swelling and shrinkage according to the treatment it receives, and also according to the atmospheric conditions in which it is placed.

Film stretches during the photographic wet processes of development, fixing and washing, and shrinks while drying.

After it is dry and the shrinkage effect continues, to a lesser or greater extent according to the atmospheric conditions in which it is placed.

The manner in which the finished film is stored, the frequency of projection, and atmospheric conditions are all causes which provoke constant changes in the length and width of a strip of film, and these changes cannot be controlled with absolute certainty regardless of the care with which film may be treated.

It is quite obvious that under these circumstances it is not possible to devise machinery which will automatically compensate for differences of dimensions due to film shrinkage. The motion picture mechanical engineer had to devise means to *accommodate* these differ-

ences and minimize their effect to such an extent that they would become unnoticeable during projection.

It is quite obvious, that film shrinkage can only be *accommodated* within certain maximum tolerances of error and this imposes upon the user the necessity of taking some precautionary measures in order to keep the films in a condition as nearly perfect as possible.

Since 16 millimeter films are mostly in use in the home, the classroom, and auditorium not equipped with special protection against fire hazards, the base of 16 millimeter film is cellulose acetate which is strictly unflammable material. The shrinkage action of acetate film is greater than that of the cellulose nitrate base of 35 millimeter film, which though a very slow burning material, is not as unflammable as the acetate base 16 millimeter film.

The building of cinemachinery with exact care, offers the greatest safeguard and assurance of film preservation.

It would be a fallacy to consider that 16 millimeter equipment can be treated with less respect than the more expensive equipment used by professionals.

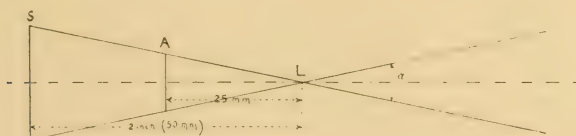


Fig. 1. Schematic drawing illustrating the angle of view of a 35 millimeter lens (L) for 16 millimeter film (A) and 35 millimeter film (B). Angle (A) is equal. The width of 35 millimeter image is that of picture synchronized with sound.

Proper maintenance is essential for good functioning. This should not be a burden to anyone inasmuch as equipment is so designed as to require very little time and effort for cleaning and lubricating it.

It would be indeed a proof of very poor judgment to underestimate the importance of accurately made and properly kept equipment.

Films, be they of the 35 millimeter or the 16 millimeter type, have a high intrinsic value. A value of actual outlay of money as well as a value which we would call of affection and every film that is worthwhile to be taken and to be kept, deserves sufficient consideration with regard to its preservation.

The Photographic Process

The principles underlying the photographic process for both 35 and 16 millimeter films are essentially the same.

The image formed by a photographic lens is collected on a light-sensitive film and rendered visible through chemical processes.

The lens mostly used in 35 millimeter motion picture photography is one having a focal length of 50 millimeters and the angle of view covered by it is very nearly equal to that covered by a 25 millimeter lens on 16 millimeter film.

The perspective effect of the projected picture, that is to say the apparent distance between points in the several depth planes of the object space is dependent upon three factors: 1—the focal length of the photographic lens; 2—the focal length of the projection lens; 3—the distance between viewer and screen.

A picture taken on 16 millimeter film projected with a 2" projection lens and viewed at the relatively short distance at which such pictures are generally viewed gives the same average effect of perspective as a picture taken with a 2" photo lens, projected with a 4" projection lens and viewed from the average distance between spectator and screen in a theatre.

It is true however, that in professional cinematography destined for exhibition in theatres, the use of a much greater range of focal length lenses has become essential in recent times.

This is due to the fact that "impressionistic shots" are being more and more used and very short focal length lenses adapt themselves admirably to these "effects" and that (this has been recognized for several years past) "close-ups" bordering portraiture work, are more pleasing when taken with a lens of a longer focal length than the 2", usually a 3". Two main reasons may be ascribed to this increase in pleasing effect, first a 3" lens gives a better balanced sense of perspective for the face of the subject, and second, that a 3" lens worked at the same aperture as a 2" has less depth of field than the latter. The backgrounds are therefore more diffused which enhances by contrast the sharpness of the modeling of the face of the subject and focused the attention of the viewer to it.

Users of 16 millimeter film can and should follow the same trend of thought that regulates the choice of a lens for the professional. Very short focal length lenses will be found very useful for obtaining a picture record wherever space is lacking for setting the camera to include an angle of view especially desired.

For close up motion picture portraiture the amateur cinematographer will find a 2" lens ideal, and longer focal lengths can be used with equal efficiency by both professionals and amateurs wherever they wish to reach inaccessible subjects, be they distant views or subjects of dangerous approach.

The user of 16 millimeter cameras must however hold in mind that whenever he dispenses with the use of a tripod and takes his pictures holding the camera in his hands (which is seldom if ever the case for the user of 35 millimeter film), he will find that the use of very long focal length lenses is quite inadvisable because of the practical impossibility of holding the camera with sufficient firmness to insure a steady screen projection.

A long focal length lens is in practically all cases used for photographing objects at a great distance, and the slightest motion of the camera results in a much greater displacement of any point of the

subject on the image plane than it will result from the use of a shorter focal length lens for the same image size.

A very interesting situation arises with regard to ways and means by which the exposure is most generally controlled. In professional cinematography for theatrical exhibition, the photographer is mostly striving for an exaltation of beauty. In other words, he disregards to a certain extent the truthful rendition of the object being photographed and strives to embellish it, also he strives to produce a picture the innumerable sequences of which can be viewed during over an hour's time with sustained attention without fatigue on the part of the spectator.

Excepting for scenes which have to carry an impression of strength of character, the professional cinematographer strives to avoid high "contrast" and to obtain a blending of highlights and shadows which eliminates harshness of contours without, however, disturbing good definition.

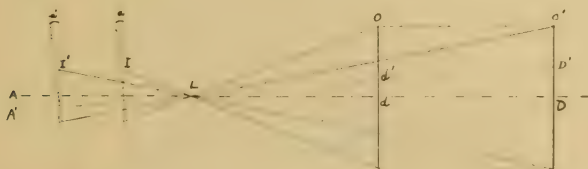


Fig. 2. Schematic drawing illustrating displacement of image for lenses of different focal length—a lens (L) of short focal length forms an image of an object (O) at (I). If the image plane is rotated for an angle (A), the center of object (O) is displaced from " d " to " d' "—A lens of double focal length forms an image at (I'). The object (O) will take position at (O') to form an image of same size as that formed by the lens of shorter focal length. If the image plane (I') is rotated for an angle (A') equal to (A), the center of the object (O') appears displaced from (D) to (D') greater than " $d d'$ ".

The effect is obtained mostly by photographing with a lens of large aperture at its maximum aperture, and controlling the exposure by means of a camera shutter of variable angular openings.

Since depth of focus of a lens is a physical factor inversely proportional to lens aperture and focal length of the lens, the professional cinematographer secures the desired effect by restricting the area of critical focus to the essential object planes. He operates with a lens of large aperture and reduces the shutter opening in order to control the admission of the light flux to the film.

Light filters are also used to a great extent for controlling exposures. Filters may be of neutral density; that is to say, filters that transmit all of the colored light radiations which compose either daylight or the artificial lights used in photographing, or selective filters, which absorb some of the radiations and permit a free passage of others.

The use of filters as a means for controlling exposures requires a profound knowledge of the sensitivity characteristics of the film, with reference to the source of light used to illuminate the subject.

It is quite evident that such technique requires highly technically trained operators who have acquired the ability of putting their technical knowledge at the service of their artistic conceptions.

Since the user of 16 millimeter films will mostly strive for a true representation of the subjects he has chosen, perfect sharpness of the picture and as great a depth of focus as possible are most desirable. Hence the amateur will obtain better results in controlling exposure by operating the lens diaphragm, which, as it is well known, controls the "depth of field" of the lens.

This fact is so strongly established and recognized that 16 millimeter cameras are not equipped with shutters of variable aperture, and manufacturers strive to produce cameras having as great a shutter aperture as possible.

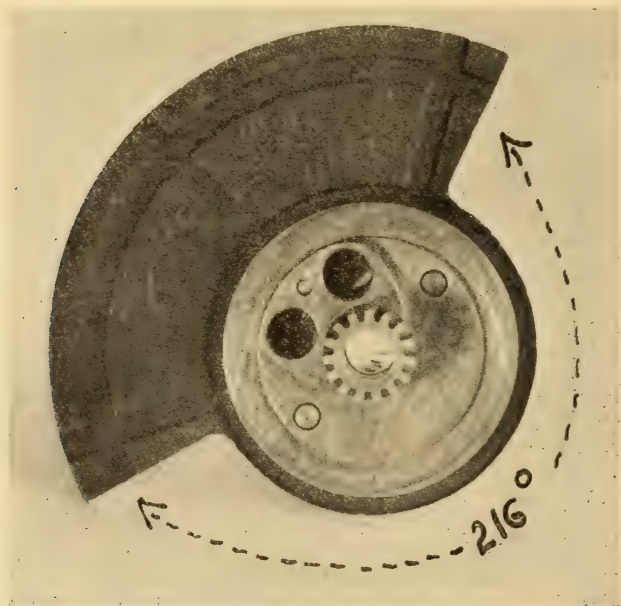


Fig. 3. The shutter of the Bell & Howell FILMO Camera model 70 which has an angular aperture of 216 degrees.

Lenses at large aperture should be used by the 16 millimeter users only when the light conditions are such that the greatest possible exposure is necessary to obtain any result at all.

Another advantage is derived by the user of 16 millimeter film through the use of as small a diaphragm opening as it is compatible with the light conditions, and that is, that for lenses of as short a focal length as one inch, the depth of field is so great for a small aperture, that for all practical intents and purposes the lens can be con-

sidered as of being of universal focus for all practical intents and purposes.

A one-inch lens, worked at F 3.5 for example, will give a sharp image of all objects located 11 feet from the lens to infinity.

The latest improvements in the manufacture and processing of Panchromatic and Supersensitive films have opened new fields to both the professional and the amateur cinematographers.

The professional can better display his technical knowledge and artistic temperament, the amateur is given means to instill greater refinements in his work and to derive a great deal of enjoyment in scanning some of the rather abstruse intricacies of the photographic processes.

More and more the 16 millimeter cinematographer is confronting problems, the solution of which can only be found through the use of apparatus designed and built with professional accuracy and through a fair knowledge of cinematographic technique, which, though based upon the main principles of photography, varies in its details with each field of endeavor.

These fields are right at this writing of tremendous importance and should interest both professionals and amateurs. They are fashioning the link which will in a short time indeed, establish a definite relation between professional and amateur cinematographers, as semi-professional and scientific still photography have tremendously contributed to the advance of both the professional and amateur photographer.

Laboratory Processing

It is well known that all 35 millimeter films are developed by the processing laboratories as negatives from which as many prints as desired are made while it is common practice to use the reversal process for the 16 millimeter film which insures only one original direct copy from which duplicates can be made if desired.

The first reason that comes to one's mind as an explanation of this procedure is that the amateur seldom requires more than one copy of the pictures taken and since only one roll of film is involved in this process, it results more economical than the negative-positive as used for 35 millimeter films.

This and the fact that film manufacturers have established service stations in great number and well equipped processing laboratories, which insure the best obtainable results and relieves the amateur from the care of doing his own processing, gives him the assurance that his films which are much more valuable than film rolls or film packs or cut films and plates as used by the still photographers are properly treated with regard to both the actual processing and the physical handling of them.

The semi-professional 16 millimeter user is very often interested in securing several copies of his picture and finds the duplicating process more or less convenient, first because of a small but still existent loss of quality, second because he must decide immediately upon the making of such duplicates before the film is run in the projector more than once or twice.

The system mostly used today when several prints are needed is to make the negative on standard 35 millimeter film and have recourse to optical reduction printing for the 16 millimeter final copies.

This method is, however, rather costly and the question naturally arises as to why negatives are not usually made on 16 millimeter films, and prints made directly from them by contact printing as it is done for professional film.

There is a quite logical answer to this question.

If we compare the size of the 35 millimeter image with that of the 16 millimeter we immediately realize that in the 16 millimeter film we crowd the same object space in an area approximately one-fourth that of the 35 millimeter film.

It is well known that the photographic image on the film is formed by an innumerable number of silver grains and grain clusters.

It is obvious that graininess controls the resolving power of the film, in other words, its ability to record small details of the object and therefore the smaller the film image the greater is the loss of details.

It can be generally accepted that the greater the speed of the film emulsion the coarser is its grain characteristic and therefore if 16 millimeter film were as rapid as the 35 millimeter the grain characteristic would prove a great disadvantage for the small films when compared with the standard larger size.

Referring to the H & D system of emulsion speed determination, the emulsion with which 35 millimeter is coated has a speed of approximately 750 as compared with 250 to 300 for the reversible emulsion of 16 millimeter films. This difference in speed accounts for the very fine grain of the small film and consequently for its high resolving power.

The slow speed of 16 millimeter emulsions would, however, be rather insufficient to satisfy the public demand if it were not possible to, so to speak, resensitize the film during the reversal processing.

It would be quite out of place in this article to enter into a detailed description and investigation of the factors involved in film processing, but the reversal process can be briefly described as consisting of the following operations.

The latent image resulting from exposure is developed as usual. During this operation, the silver halide affected by the light is transformed in the tiny silver grains and grain clusters which form the negative image. The silver halide of the emulsion which has not been reacted upon by the developer is still sensitive to light. It is obvious that if the silver particles forming the first, or negative, image are bleached and the remaining silver halide is exposed to an actinic light, a latent image is formed which, if developed through the normal developing process, will form a photographic image which will be positive.

It is through an accurate control of this double development and intermediate "flashing" (exposing to light) that the sensitivity "boosting" effect is secured without increase, in fact with a reduction of graininess.

This does not mean, however, that one should nurse the thought that the semi-professional users of 16 millimeter are vainly hoping to ever have a film at their disposal which will give them results equally as good as those obtained with professional films through the negative-positive process. The wheels of progress are constantly turning and both the film manufacturers and the laboratory experts will devise means through which public demand will be satisfied.

It remains to analyze the method of taking the negative on 35 millimeter film and making prints by optical reduction on 16 millimeter film. Very excellent results are obtained by this system and again the graininess characteristic of the film plays an extremely important role.

The grain of positive film is so small that it is negligible, this being partly due to the low speed of these emulsions. Now a certain object area is taken on the image area of 35 millimeter film and details are registered according to its resolving power. This large image is reduced in size on 16 millimeter positive film, the resolving power of which is vastly greater than that of the negative.

The grain of the original negative is reduced through optical printing and the negligible entity of positive grain finally insures prints in which no details are sacrificed.

Projection

Qualifying a good picture as a finished product, that is to say with regard to its appearance on the screen, its attributes are:

FIRST: Good Definition.

SECOND: Luminosity.

THIRD: Steadiness and absence of flicker.

It is quite obvious that in order to secure good definition in projection, the original negative and prints must be sharp, and this is dependent upon the camera lens system and the accuracy and skill of the operator.

But even a perfectly sharp film could not be projected as such with a defective or ill-devised projection optical system.

The characteristics of the projection lens differ from those of a photographic lens, and opticians have devoted as much time, study and energy to the study and development of this branch of optics as to that pertaining to photographic lenses.

Needless to say that the same care which is essential for the good functioning of a photographic lens is also essential for obtaining the best possible results from a projection lens.

The flatness of field and great luminosity of modern projection lenses insure for both the 35 and the 16 millimeter films a pleasing and brilliant screen image.

The luminosity of the screen image must be considered under two different aspects for the professional 35 millimeter film, and the 16 millimeter.

In the first, each picture frame is called to stand a great amount of magnification averaging approximately four hundred times diametrically, while the average magnification of 16 millimeter film is

only approximately seventy-five times. This being due to the fact that theatrical films are projected for simultaneous viewing by several hundred, even a few thousand people, while 16 millimeter films are usually shown to a much more limited audience.

The necessity of a much greater illumination for the first is obvious, and the source of light usually used in the carbon arc, though incandescent lamps of high wattage have been used with good success.

For the 16 millimeter film incandescent lights have been found amply sufficient with regard to illumination and much more recommendatory because of the elements of safety and greater ease of operation.

A two hundred and fifty watt lamp is amply sufficient for home use where an excess of screen brilliancy would perhaps result fatiguing to the eye.

For the projection of semi-professional films for educational, industrial or commercial use, lamps of higher intensities can be advantageously used, and lamps burning at low voltage and high amperage have been designed for this particular purpose. Better still, the Bell & Howell Company has put on the market a three hundred seventy-five watt lamp which offers the possibility of a brighter screen image than heretofore attainable, and which, through a variable resistance, can be made to burn at any desired wattage, thus affording the possibility of regulating the brilliancy of the screen according to the condition of projection, the length of the throw and the density characteristic of the film.

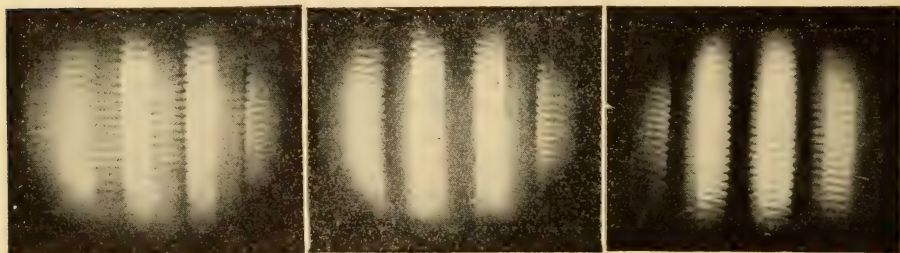


Fig. 4. A—Reflected filament images properly focused and intermeshed. B—Filament intermeshed but badly out of focus. C—Filament properly focused but not intermeshed.

The crater of a carbon in an arc light, which is the main source of illumination in professional projection, produces a relatively small surface of intense brilliancy and the condenser system is so designed and placed in the projection machine that all of the rays of light, those directly incident upon the condenser and those reflected by the refractor usually used in those lamps, fill the condenser and are brought to an intensely illuminated spot fully covering the projector aperture.

The same attributes are essential in 16 millimeter projection. Furthermore, the fact that the filaments of an incandescent lamp

do not form a solid mass of light necessitates that the reflector back of the lamp be susceptible of being adjusted, so that the image of the lamp filaments formed by the reflector can be made to enmesh the image of the same filament formed by the condenser and evenly cover the film aperture.

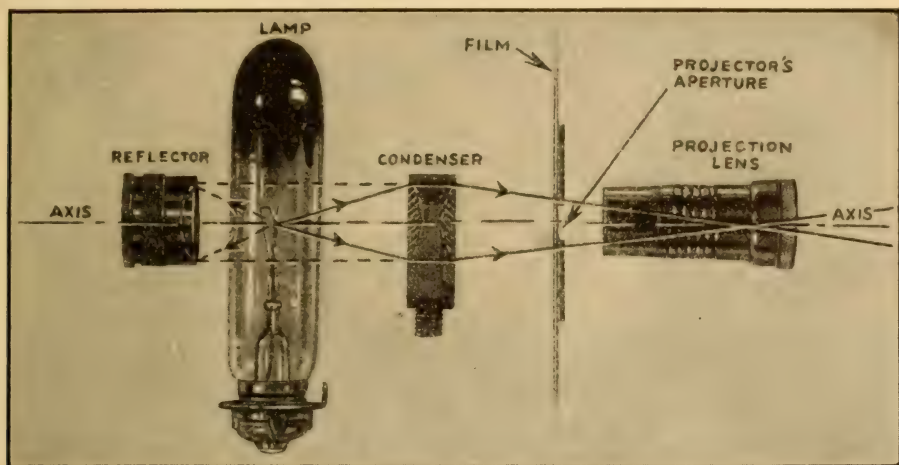


Fig. 5. Optical system of the FILMO Projector.

It is well to mention here that the Kodacolor system of 16 millimeter color films demands good care in the adjustment of the whole optical system and as perfect as possible enmeshing of the images of the lamp filaments.

Incidentally, this color process which is available only in 16 millimeter demands also as great a source of light as possible.

This is due to the fact that the colored filter absorbs a good amount of light, resulting in that the size of the screen image is limited mainly by the flux of light available.

A 375-watt lamp permits a good Kodacolor projection on a 30"x40" screen.

Although the incandescent lamps used in 16 millimeter projection are eminently efficient, it is quite advisable that the screen upon which the pictures are projected offer a greater reflective power than those used in public auditoriums for professional films.

This is especially true of 16 millimeter films used for educational and industrial purposes, which are shown to a relatively great number of people at once.

In theatres, it has been found that it was even possible to perforate the screen with a great number of small orifices to permit a free transmission of sound (the speakers being placed behind the

screen). These perforations considerably reduce the reflective power of the screen and in consequence the brilliance of the screen image. To compensate this loss the projection machines are equipped with arc lamps operating at a high amperage.

The 16 millimeter screen is designed to save as great a reflecting power as possible. The pearl beaded screens and especially some of the silver or aluminum-surfaced ones, respond very well to the exigencies of 16 millimeter projection.

Extra bright screens with surfaces only slightly roughed and a high reflecting power are indeed essential, especially for projecting Kodacolor pictures where, as said above, the size of the projected image is limited mostly by the brilliance attainable.

Next to brilliance of screen image, and perhaps of greater importance, is its steadiness and absence of flicker.

Steadiness of the image is secured for both 35 and 16 millimeter projection through good design and accurate manufacture of both cameras and projectors.

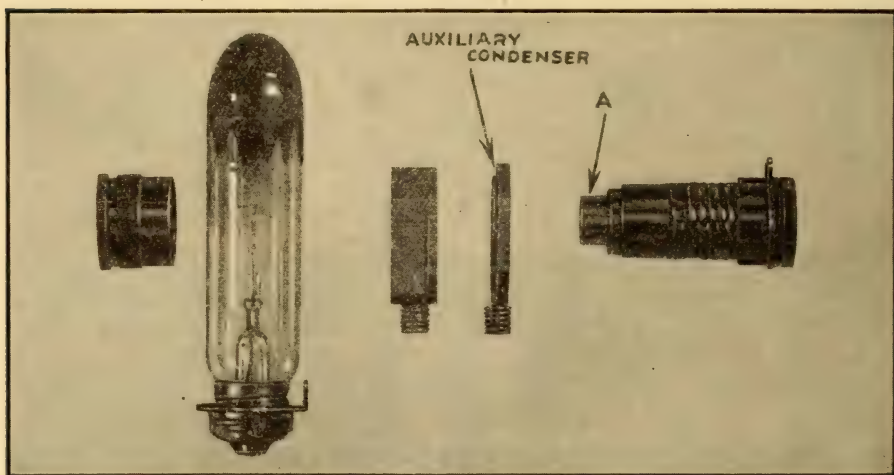


Fig. 6. Film projector optical system for Kodacolor picture projection.

Again the motion picture mechanical engineer meets the shrinkage problems mentioned in the first section of this article and again perfect registration of each film image must be secured.

Since Acetate 16 millimeter films shrink more rapidly and to a greater extent than nitrate films, it is most advisable to take some precautions in order to insure their flexibility and maintain their dimension within the tolerable limits. Manufacturers of motion picture equipment have devised special cans and containers with humidior compartments which answer admirably film storage requirements.

But aside from mechanical considerations a great deal of attention had to be paid to the physiological effect that makes motion pictures possible.

It is known that motion pictures could not exist if nature had not favored us with the phenomenon of persistence of vision.

Each single picture frame is successively brought in exact position at the projector aperture at a rate of speed of 16 frames per second for silent, and 24 frames per second for pictures synchronized with sound. A shutter intercepts the projection light during the periods of film motion and allows the passage of the light through the film onto the screen during the periods at which the film is stationary.

During the periods of light occultation, the screen image is still visible by the human eye through the faculty it has to retain image for a certain length of time.

It is obvious that the periods of occultation and visibility must be sufficiently rapid so that the projector's shutter uncovers a frame before the image of the preceding one has ceased to "persist" in the retina of the eye.

Experimentation has disclosed that forty-eight occultations and consequent exposures per second are necessary for the eye to have the impression of looking at a constantly illuminated screen.

Since only 16 or 24 picture frames are taken per second through the camera the necessary number of occultations can be reached by controlling the rotative motion of the shutter in such manner that it covers and uncovers each film image three times for speed of 16 and twice for 24 speed while the film is stationary at the gate and displace the film during one period of occultation.

Prior to sound pictures, when 35 millimeter pictures were photographed at a speed of 16 frames per second, the shutter of the professional projector was usually in the form of a disc with three blades. It was made to revolve at 16 revolutions per second and the film mechanism was so synchronized with its rotation that the film would be displaced at the aperture during the occultation period of one of the three blades.

Since sound pictures have standardized a photographic speed of 24 picture frames per second, shutters with only two blades are used rotating at a speed of twenty-four revolutions per second.

As opposed to the above, 16 millimeter projectors are usually equipped with shutters rotating at high speed. The film remains stationary during three complete revolutions of the shutter.

The flux of light transmitted for each frame depends upon the angular aperture of the shutter.

It is evident that the shorter the periods of occultation, the greater is the time during which the eye is perceiving the screen image, and shorter the time during which "persistence of vision" is dependent upon.

The drawing illustrates a complete cycle of the shutter of the *Filmo* projector which, as shown, has an angular aperture of 220°, which insures absolute absence of "flicker" even when the projector is operated at a speed much lower than 16 pictures per second.

Resume

As an appendix to the above necessarily quite incomplete discussion and in order to assist the reader in the understanding of the merits of both 35 and 16 millimeter films, the main characteristic and technical aspects of both are here listed in parallel columns.

Cost

35 Millimeter

A 35 millimeter professional camera outfit as used for studios, industrial or news weeklies, requires an investment of from \$2000.00 to \$4000.00 and higher, according to the accessories needed and to the particular work it is called upon to perform (Ultra-speed, sound, color, etc.)

Small, compact, spring driven cameras for 35 millimeter are available, costing from about \$200.00 to \$600.00 depending on accessories.

35 millimeter portable projectors cost about \$300.00 to \$400.00.

Laboratory work for the negative-positive process involves a cost of approximately from \$0.10 to \$0.15 per foot of silent negative (cost of film and processing at exclusion of production cost). Additional prints \$0.04 per foot.

35 Millimeter

A professional outfit, complete with cases, weighs from 40 lbs. to 150 lbs.

The spring driven 35 millimeter cameras weigh from 8 lbs. to 25 lbs.

35 millimeter portable projectors weigh about 60 lbs.

16 Millimeter

Small, spring driven cameras are available in a variety of models, differing in versatility, size and weight.

Cost runs from \$100.00 to \$300.00.

16 millimeter projectors, suitable for industrial work, run about \$150.00 to \$300.00.

A complete 16 millimeter outfit, with full assortment of lenses and other accessories, can run up around the \$1000.00 mark.

16 millimeter film processed costs \$6.00 or \$7.50 per 100 feet. Duplicate prints, \$5.00 per 100 feet.

Reduction print from 35 millimeter negative to 16 millimeter positive, \$2.00 to \$3.00 per 100 feet of 35 millimeter film corresponding to 40 feet of 16 millimeter film.

Weight

16 Millimeter

A 16 millimeter camera with minimum accessories weighs as little as 5 or 6 lbs. The more elaborate outfits weigh up to 20 or 25 lbs.

16 millimeter projectors weigh from about 10 lbs. to 20 lbs.

Camera Film Capacity

35 Millimeter

Studio cameras are equipped with exterior magazines of 400 and of 1000 ft. capacity. (Maga-

16 Millimeter

Practically all 16 millimeter cameras have a capacity of 100 ft., (not including leaders at

zines are loaded beforehand in dark room. Cameras are threaded in daylight).

Spring driven hand cameras are nearly all of 100 ft. capacity, not including leaders at each end of roll to permit daylight loading and unloading.

Theatre projectors have a capacity of 2000 ft.

Portable projectors a capacity of 1000 ft.

each end of roll to permit loading and unloading in daylight).

Standard capacity 400 ft. corresponding to 1000 ft. of 35 millimeter film.

Some 16 millimeter projectors are equipped for reels of 400 ft. capacity equalling 5000 ft. of 35 millimeter film.

Running Time

35 Millimeter

1000 ft. magazine of film, at 16 pictures per second camera speed, lasts about 16 minutes (one foot of film per second). Camera is usually motor driven, but can be cranked by hand.

100 ft. spring cameras usually run about 55 ft. at winding. If equipped with hand crank, the whole 100 ft. roll can be run off without stopping. Time $1\frac{1}{2}$ minutes. Sound pictures are taken at a speed of 24 pictures per second.

16 Millimeter

100 ft. roll of 16 millimeter lasts $2\frac{1}{2}$ times as long as 100 ft. of 35 millimeter film. Most 16 millimeter cameras run about 25 ft. at winding. Time about $1\frac{1}{4}$ minutes.

If equipped with hand crank, the entire roll can be run off without stopping. Time about $4\frac{1}{4}$ minutes.

The speed of the best camera equipment can be automatically regulated from approximately half below to considerably above normal.

Lighting

35 Millimeter

The professional and especially the studio cinematographers use artificial lighting for modeling the subject.

A good amount of lighting equipment is used and controlled through distance from the subject and proper diffusing of each source of light for obtaining the desired effects created by the artistic conception of the cinematographer.

In outdoor cinematography the lighting is generally controlled through the use of reflectors.

16 Millimeter

16 millimeter film users are usually limited in the number of lights they may use through considerations of economy and current available.

The placing and diffusing of the lights available is dictated solely by the users' artistic conception and knowledge of film speed.

The newest supersensitive films should prove very valuable to 16 millimeter cinematographers, as they offer greater latitude in lighting control.

*Lenses**35 Millimeter*

A 2" lens is used as standard for 35-mm work. Usually is of F 2 or F 2.5 speed.

Great care has to be exercised in focusing fast lenses when used on 35 millimeter cameras.

Only lenses of the highest quality of both design and construction should be used for both 35 and 16 millimeter cinematography.

Great care is exercised in mounting lenses so as to insure perfect alignment and setting.

16 Millimeter

A 1" lens gives the same perspective on 16 millimeter film as the 2" lens does with the 35 millimeter size. F 3.5 is the usual maximum speed for exterior work.

Lenses used for 16 millimeter work have greater depth of field, (often called depth of focus) than those used for 35 millimeter work. Therefore, they do not have to be stopped down as far to get the same results. Lens apertures of F 1.8, F 1.5 and even F 0.99 are used on 16 millimeter cameras.

*Special Camera and Photographic Effects**35 Millimeter*

35 millimeter cameras are to be preferred where elaborate or special effects are desired.

16 Millimeter

16 millimeter cameras and accessories are now available, that almost any professional effect can be reproduced, though not quite as easily.

*Slow Motion**35 Millimeter*

Ultra-speed attachments are available for professional cameras, permitting 1000 ft. runs at speed of from 128 pictures per second up to about 250.

Cameras operating at higher speeds are used only within the research laboratory.

16 Millimeter

Combination cameras with variable speeds (from 16 to 64) are available. Run about 15 seconds at 64 speed.

A special 16 millimeter slow motion camera is available, running at 6 seconds at 128 (normal slow motion) speed.

*Color**35 Millimeter*

Special mechanisms and films are available for taking both color and black and white pictures with the same camera.

These use the bi-pack process such as Multicolor.

The Technicolor process requires special cameras.

A certain skill is required for taking color 35 millimeter films.

16 Millimeter

Attempts are being made to make 16 millimeter reduced prints from 35 millimeter bi-pack negatives. Nothing is commercially available at the time of writing.

The Kodacolor process is exclusive to 16 millimeter film, and is the only three-color process available for general use, not requiring particular skill.

The color rendition of this process is the best available.

Sound

35 Millimeter

Sound-on-film and sound-on-disc pictures are available, and used, for non-theatrical as well as for theatrical exhibitions.

The taking of pictures synchronized with sound requires a thorough knowledge of all the technical factors involved.

16 Millimeter

16 millimeter reduced prints can be made from 35 millimeter sound pictures and the same record used in perfect synchronism.

If the 35 millimeter negative has the sound-on-film, the sound can be re-recorded onto disc and still used with perfect synchronism.

16 millimeter sound-on-film is *not* commercially available as yet.

A silent 35 or 16 millimeter production can be synchronized with sound (lecture, musical score, or sound effects) if it has been photographed at a speed of 24 pictures per second.

Lip movements cannot be successfully synchronized with the spoken word in re-recording. Synchronism of this nature can only be secured by recording the spoken word at the same time as the speaker utters the words, while he is being photographed.

Reduced Prints

16 millimeter reduced prints can be made from 35 millimeter negatives. This alternative is used for a large number of purposes as it gives all the advantages of 35 millimeter from the camera angle. That is, professionally made negatives of highest quality, with professional effects and quality, can be printed onto 16 millimeter film to permit them being shown by the small, compact, and efficient 16 millimeter projectors now available.

When one realizes that 16 millimeter projectors can now show pictures 8 ft. x 10 ft. (and even larger), of sufficient brilliance and quality to be seen comfortably by audiences of one, two or even three thousand, the value of reduced prints can readily be appreciated.

There are many factors involved in the choice between using 35 millimeter negatives and contact prints, 35 millimeter negatives and 16 millimeter reduced prints, 16 millimeter reversal positives and duplicates, or 16 millimeter negatives and contact prints.

Here the question of quality enters. Is the work critical enough to warrant paying the price of the utmost in quality? What is the best balance between quality and price? Which is the best combination to use for quality and price for a few highly specialized pictures; for large distribution of reasonably good quality pictures, etc.?

Individual requirements introduce great complexity at this point, and it is suggested that inquiry be made of the equipment manufacturer, for recommendations as to the best alternative to adopt for each and every specific purpose. However, there are many technical aspects involved, such as grain size, illumination, permissible enlargement, etc., which have a distinct bearing on the quality of the final presentation.

A parallel comparison of these factors is now offered for analysis.

Prints Quality

35 Millimeter

35 millimeter contact prints naturally possess the utmost in quality. By photographing with suitable negative film, giving correct exposure and correct development to the negative, and with proper adjustment of printing lights, positive prints of the highest quality are assured.

Professional film processing has been made the subject of continuous scientific investigation which has resulted in great efficiency in handling the numerous and complicated phases of laboratory procedure for both 35 and 16 millimeter films.

16 Millimeter

16 millimeter reduced prints register the fine quality of 35 millimeter negatives. For screen sizes up to 5 ft. x 7 ft., reduced prints will show practically as clear and as sharply defined a picture as a 35 millimeter contact prints from the same negative. They have satisfactory quality for screen sizes up to 11 ft. x 14 ft.

16 millimeter reversal positives are entirely satisfactory for screen pictures up to about 5 ft. x 7 ft.

16 millimeter duplicates are now nearly as good in quality as the originals, if care is taken to make them before the originals show effects of wear due to prolonged projection.

Grain is generally quite noticeable in 16 millimeter contact prints. This is the principal objection to them.

The Projection of Non-Theatrical Films

At this point, a consideration of the projector and its efficiency and other attributes, becomes logical. The weight, portability, safety, ease of operation, etc., of the projector often becomes the deciding factor as to whether 35 millimeter or 16 millimeter film is used.

The 16 millimeter projector has many advantages over the 35 millimeter projector, and this is one of the main reasons for the widespread use of reduced prints—to say nothing of the success of 16 millimeter pictures in general.

That trite saying about "the proof of the pudding", is nowhere so applicable as it is to the final result on the cinema screen.

The essential factors involved in projection will now be considered.

Weight

35 Millimeter

35 millimeter "portable" projectors weigh about 60 lbs.

Reels of 35 millimeter film weigh about 8 or 10 lbs. each, and must be shipped by express in iron cans weighing 10 to 20 lbs. each.

16 Millimeter

16 millimeter projectors weigh from 11 to 20 lbs. complete.

Reels of 16 millimeter film weigh about 1½ lbs. each. (400 ft. of 16 millimeter film runs as long as 1000 ft. standard film)

16 millimeter film can be sent by parcel post.

Film Shrinkage

35 Millimeter

Shrinkage of nitrate film is not excessive under average circumstances.

Safety film—same as 16 millimeter.

16 Millimeter

It is necessary to keep 16 millimeter (safety) film in humidors. Shrinks quite a bit if allowed to dry. Not quite as pliable or tough as nitrate film.

These disadvantages are offset by safety factor.

Fire Hazard

35 Millimeter

Though NITRATE 35 millimeter film is a slow burning film, fire regulations must always be complied with.

Usually booth and licensed operator are required.

16 Millimeter

ACETATE 16 millimeter film is non-inflammable.

This applies to all 16 millimeter film.

No special precautions are necessary for operating a 16 millimeter projector.

Illumination

35 Millimeter

35 millimeter portable projectors use 1000 watt and 500 watt lamps.

16 Millimeter

The most powerful illumination available, at present, for 16 millimeter projection is the 375-watt lamp.

Efficiency of Intermittent

35 Millimeter

Best 35 millimeter projectors have 6 to 1, while most have 4 to 1 movements, i.e., the light is cut off for $1/6$ or $1/4$ of the cycle.

Some flicker is usually noticeable on the screen.

16 Millimeter

Most 16 millimeter projectors have 9 to 1 or 6 to 1 movements. This allows more light on the screen for each cycle, so the "screen efficiency" of the lamp is much higher than with 35 millimeter projectors.

No flicker is visible at regular speed.

Ease of Threading and Operation

35 Millimeter

All 35 millimeter projectors have enclosed film magazines. None are as easy to thread or use as the 16 millimeter projectors.

16 Millimeter

Owing to safety of film, reels are exposed and easy to get at. Simplicity of use is one of the keynotes of 16 millimeter projector design.

*Accuracy of Construction, Noise, Life***35 Millimeter**

35 millimeter projectors are very accurately constructed. Owing to the weight and inertia of the 35 millimeter film, they tend to be much noisier and wear more rapidly than the average 16 millimeter projector.

16 Millimeter

16 millimeter projectors have to be constructed to a very precise degree. They tend to be much quieter and as a general rule, do not need attention as often as 35 millimeter projectors under the same conditions of service and steadiness of projection.

*Cooling***35 Millimeter**

Some 35 millimeter portable projectors are cooled by a blast of air generated by a fan built into the machine.

16 Millimeter

The best 16 millimeter projectors are cooled most efficiently by built-in fans.

*Other Projection Features***35 Millimeter**

Some 35 millimeter projectors can be stopped to show a single frame for short periods.

No 35 millimeter projectors are designed to operate in reverse.

16 Millimeter

Most 16 millimeter projectors are equipped with means of showing single frames as still projection.

Several 16 millimeter projectors can be operated in reverse just as easily as forwards. Used for trick effects and in lecture work, for going back to a previous scene for quick reference, etc.

*Size of Audience***35 Millimeter**

For showing to very large audiences—2000 and up.

16 Millimeter

For audiences up to about 2000.

Summary

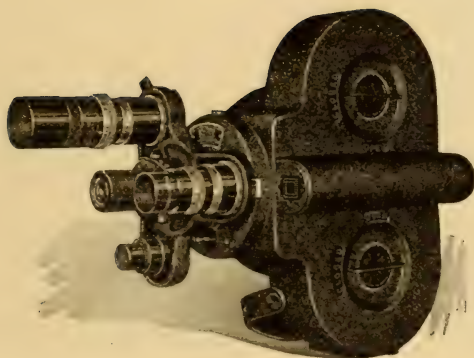
From the foregoing, we reach several definite conclusions regarding the equipment to be selected for certain definite classes of work:

First—Where quality is paramount, where many prints are to be made, and the pictures are to be shown to very large audiences: *Then 35 millimeter prints from 35 millimeter negatives should be used.*

Second—Under the same conditions, except where the pictures are to be shown to audiences up to, say, 2000 and where auditorium is not equipped with regulation booth: *Then 16 millimeter reduced prints from 35 millimeter negatives are indicated.* This combination is also recommended where the highest quality is desired, compatible with portability and ease of operation.

Third—Where a large number of prints are to be used, where portability and expense are important considerations: *Then 16 millimeter contact prints from 16 millimeter negatives are suggested.* These are very satisfactory, in spite of a greater graininess of the prints. The alternative to the above is the use of *16 millimeter duplicates from 16 millimeter positives.* After making about six to ten duplicates, the cost of this method becomes greater than the use of 16 millimeter contact prints.

Fourth—Where one, or only a few prints are needed of very good quality, and where expense is the principal item: *Then the use of 16 millimeter camera and 16 millimeter reversal film is definitely indicated.*



Filmo 70-C Camera



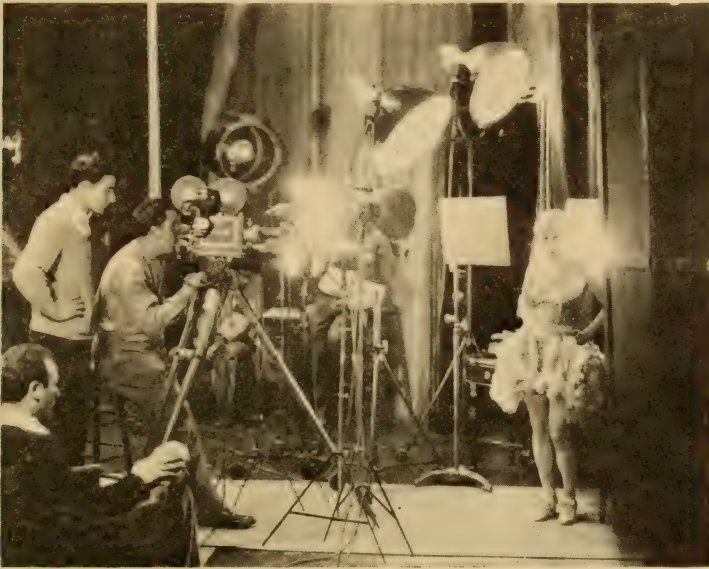
Studio Atmosphere

Adolph L. Schafer

WHAT THEY USE IN HOLLYWOOD

IN THE following pages we present a varied collection of pictures of the technical and mechanical gadgets and equipment developed in the picture industry and now in use in the big studios in Hollywood. To those readers who are many thousands of miles from the picture making center we feel that these pictures with short explanations will be of some assistance. At least, it will keep the readers in touch with just what is going on, in the equipment line, in Hollywood, and will illustrate the methods used to accomplish certain objectives.

From year to year we hope to make this one of the most interesting sections of this publication.—The Editor.



LIGHTS

An excellent illustration of the use of lights in making a closeup. The Camera-man is Hal Mohr, A.S.C. The lady is Evelyn Brent.



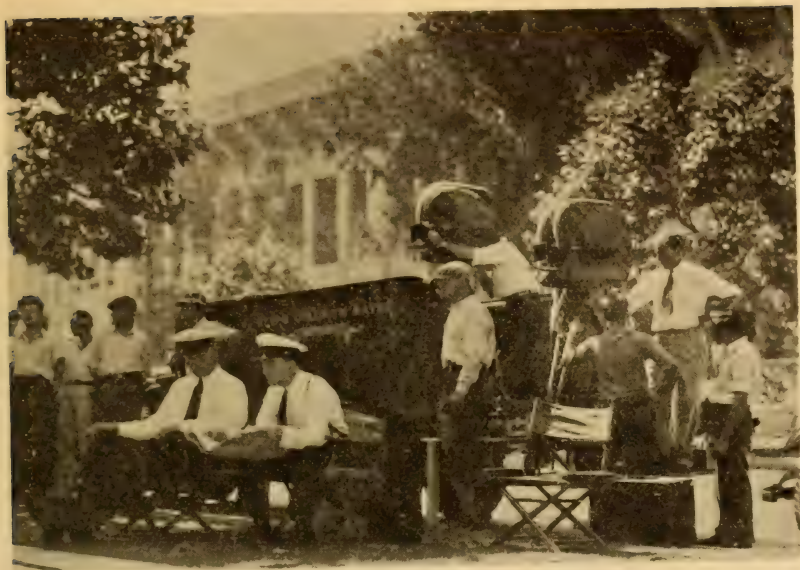
ACTION

Here we see the filming of a horse race. Note how the microphone is suspended over the track.



REHEARSAL

A general idea of equipment for an interior is here shown. Note the new "bomb" microphone hanging above John Gilbert.



BLIMPS

You see here how the cameras are silenced by "blimps," which have been perfected to a great degree.



HOW IT'S DONE

Here we have a camera crane mounted on a movable platform. With it those remarkable shots you wonder at are made. The crane can be swung about in a circle, raised or lowered, while the whole thing is pulled along to keep in line with the action.



CAMERA CRANE

A close view of a camera crane, devised at M-G-M, and made entirely of aluminum, giving lightness with strength. Those peculiar angle shots are made easy with this.



ANOTHER VIEW

Here is another view of the M-G-M aluminum camera crane. This gives an excellent idea of its construction and means of operation.



LOCATION

The cameramen and sound technicians meet all conditions on location. Here we have a floating platform to care for camera and the microphone, and the director.



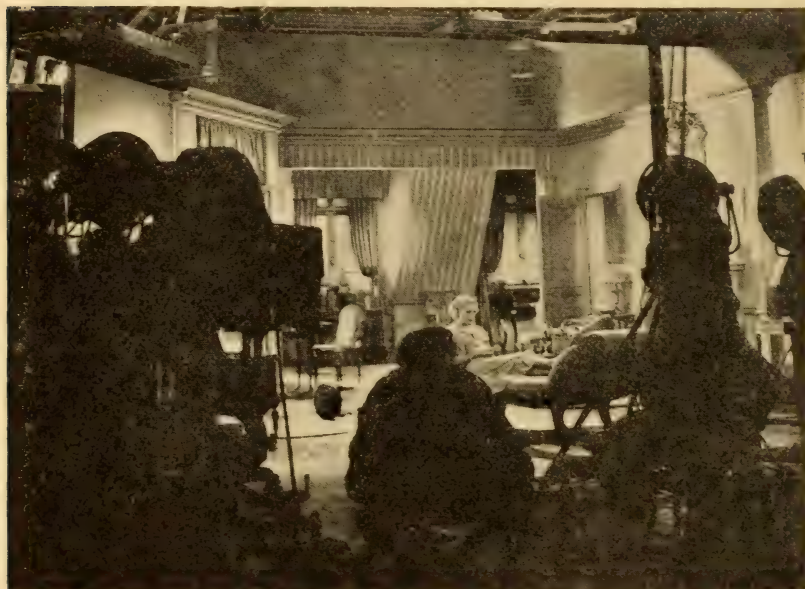
ANOTHER CRANE

Universal uses this type of camera crane. Despite its bulk, it can swing the camera at a remarkable speed. This is a picture made during the filming of "The Spirit of Notre Dame."



SILENCE

This is one of the camera silencing devices used in Hollywood. Note camera and cameraman are on a "Dolly," or platform on wheels which makes possible those follow shots.



ON THE SET

An excellent picture showing how lights are placed for this scene.



LIGHTING EFFECTS

Remember this scene in "The Modern Age"? This was how the lights were arranged.



EXTERIOR LIGHTING

It takes more than sunshine to make pictures as this scene shows. Note the number of lights used on Miss Joan Crawford.



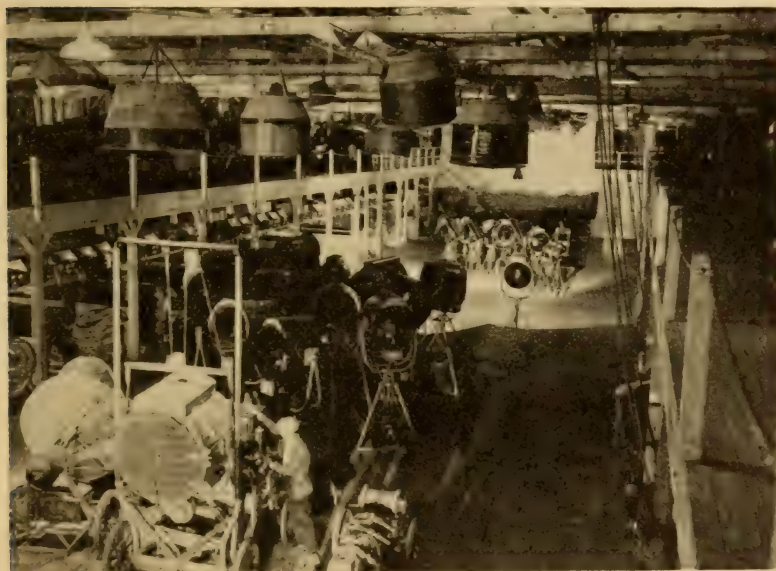
CLOSE-UP LIGHTING

A very good illustration of light placement for effective close-up lighting.



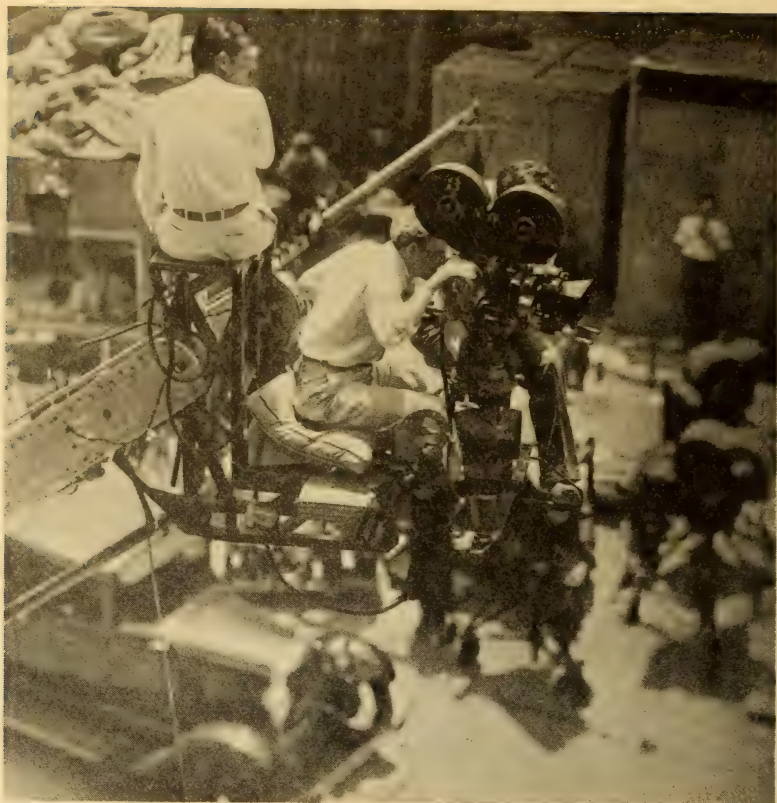
GETTING ACTION

Even in Westerns the camera and microphone keep right with the players by means of the camera "Dolly." Note use of reflectors.



ELECTRICAL SHOP

This is part of Paramount's lighting equipment at Ho'lywood. Gives some idea of vast amount of lamps required.



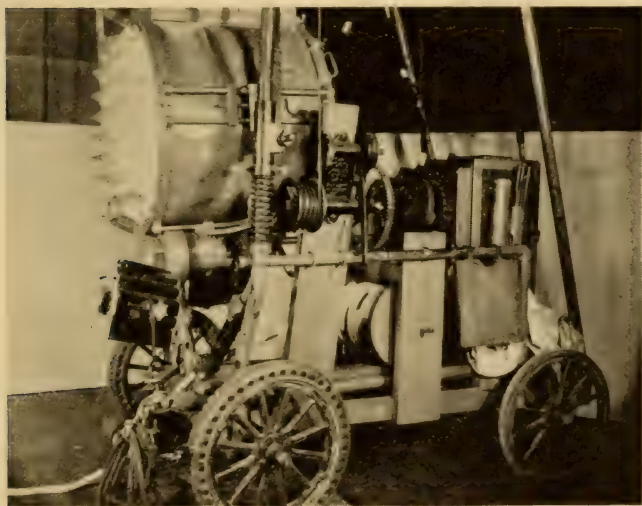
UP IN THE AIR

You, perhaps, wondered how some of those striking scenes in "Street Scene" were secured. Well, here is how some were taken. The camera is mounted on a giant crane at United Artists' studios and swings over the heads of the players and over passing traffic.



TECHNIQUE

When Willie Hoppie, famous billiard expert, made a short at M-G-M this was the lighting and camera set-up that produced such effective results. In this photo you see results and how accomplished



LARGEST AND SMALLEST

Here are the largest and the smallest spotlights used at Paramount's Hollywood Studios.



MICROPHONE PLACEMENT

Voices must be picked up these days or all is lost. Here we see one microphone placed high and another low at M-G-M. No chance of going wrong here.



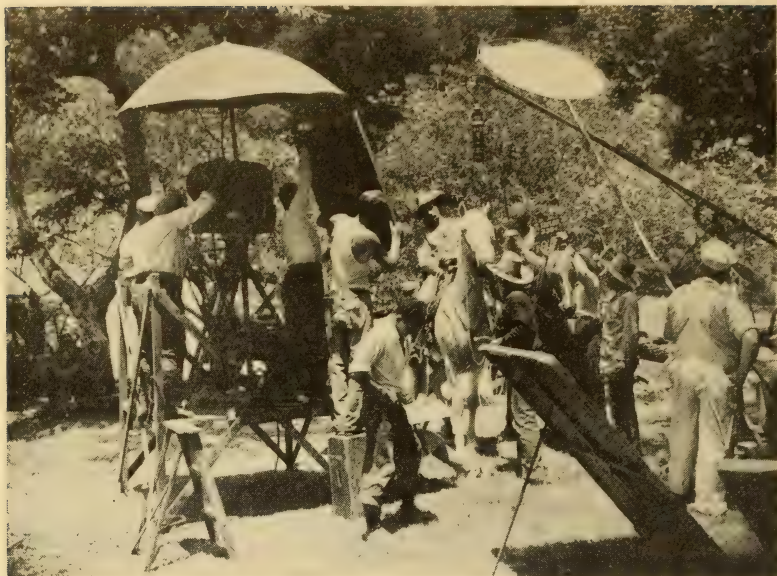
HORSES

An example of equipment needed on location since sound came along. Horses' hoof-beats must be recorded. Cecil de Mille is here shown directing a scene in "The Squaw Man." The thing that looks like a hornet's nest is the "mike".



FOOTBALL EQUIPMENT

Parallels, "blimps", sound trucks, reflectors and microphone booms all played a big part in filming "The Spirit of Notre Dame". This shows some of the equipment.



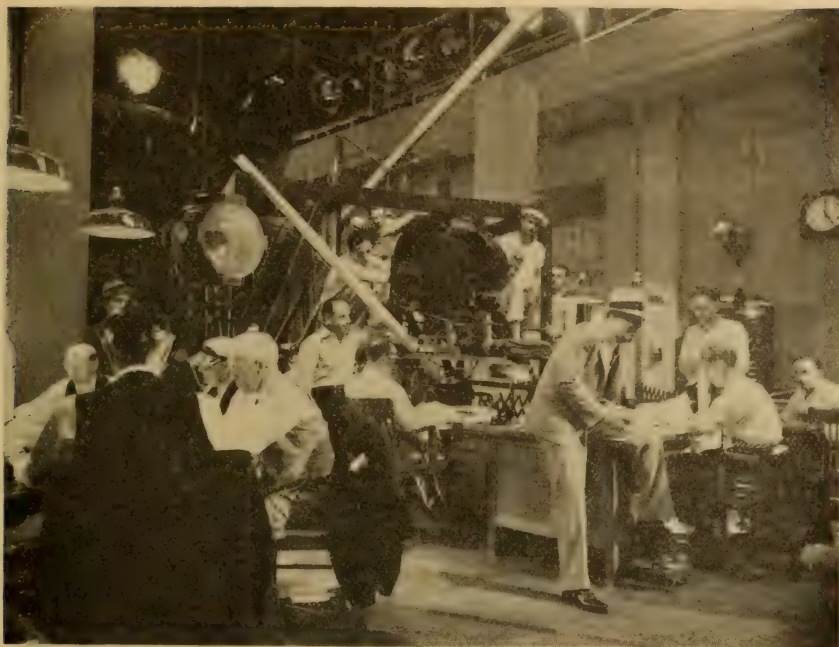
WHOA!

When you see an out-door scene you seldom realize that all this equipment had to be used. A good example of what you need for a good exterior closeup.



MOVING SHOT

This is how they make one of those action shots in which the camera goes along giving you a moving closeup. Simple. Camera mounted on a "Dolly." Even reflector has to move.



CITY ROOM

An example of how the cameraman has to work to get proper effects. Note lighting arrangement and camera placement in this newspaper office scene from "Consolation Marriage" at R-K-O.



ON THE FARM

Another example of how to make exteriors.



ON WHEELS

Making a moving shot at RKO. Notice cameras, sound equipment and reflectors all on wheels for mobility.



STUDIO WINTER

It was 112 in the shade when this winter scene was made at RKO. You can see, yourself, how it was done.



LIGHTING A COURTROOM

If you want the latest advice in lighting a big room, study this picture, a scene from R-K-O's "Are These Our Children?", directed by Wesley Ruggles. The picture tells its own lighting story.



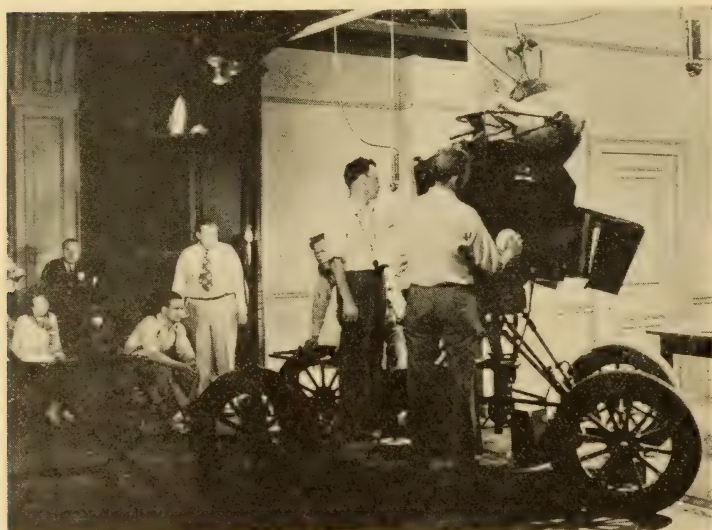
UP!

To get a shot of a po'e-cualter coming up over the bar, this platform for the cameras was constructed at MGM.



TRAVELLING CAMERA

Here is the unique travelling camera and microphone crane used at RKO-Pathe in filming a street scene in "Her Man".



MOBILITY

Just try lifting this sound camera. But on the "Dolly" here shown you can move it with a finger.



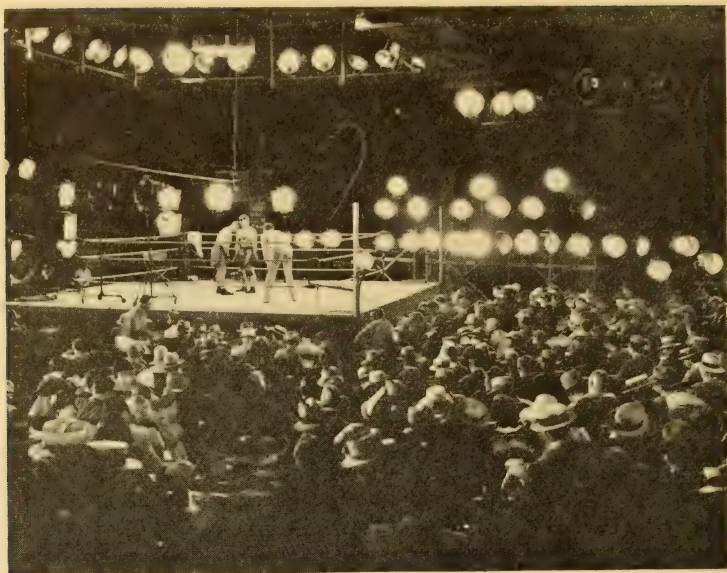
EFFECTIVE LIGHTING

An excellent example of the cameraman's art of lighting. Note the effective manner in which all four characters are brought out.



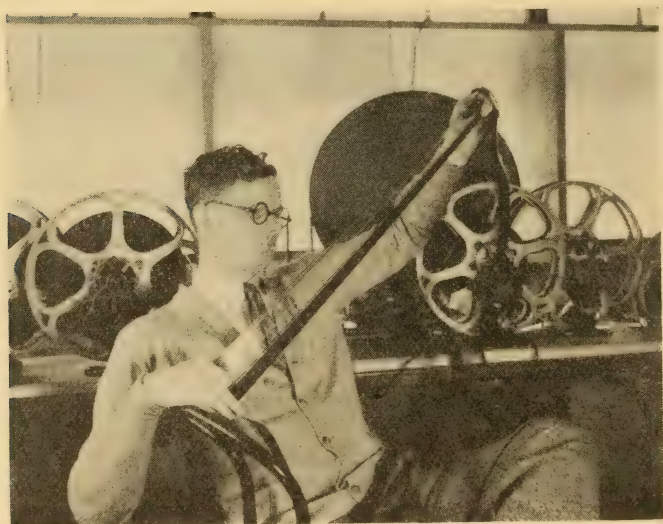
GROUNDWORK

Edgar MacGregor and Nick Grinde start from the bottom up to get this scene. An excellent illustration of how some unusual situations are brought to the screen by the Hollywood cameramen.



A STUDIO PRIZE RING

This ring was erected at Warner Bros'. studios for the Joe Brown picture, "Hold Everything". The microphone hangs over the ring. How it was lighted may be seen readily.



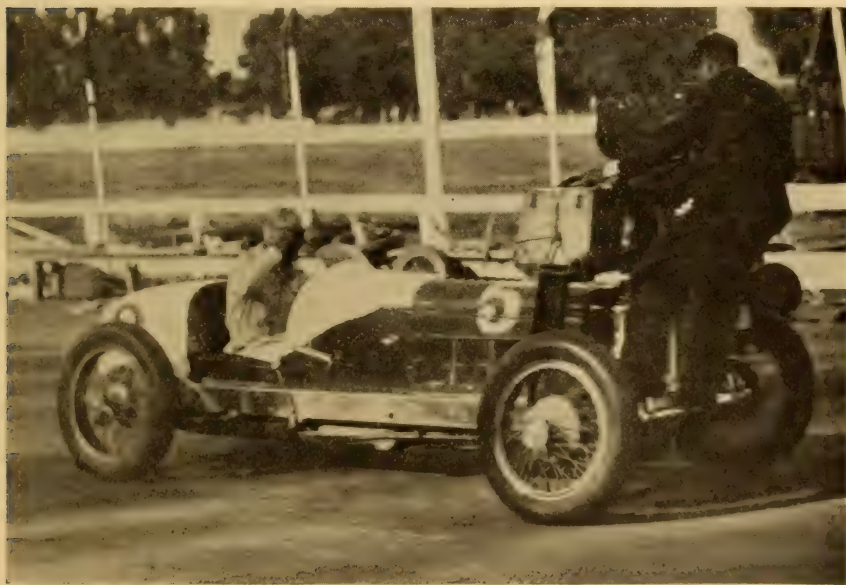
EDITING

This photo shows a film editor cutting and editing sound track and picture.



EFFECTS

To get the proper effect in this shot of Marion Davis and Lawrence Gray, the cameraman has taken to the air. This was to get shots of the players while they were swinging. With the arrangement perfect closeups were obtained as the camera swung with the players.



THRILLS

You often wonder how the cameraman secures closeups of players in auto races and the like. Well, here's the answer. The picture tells its own story.



BOOSTER LIGHTS

Here we see the use of "booster lights" in an exterior scene.



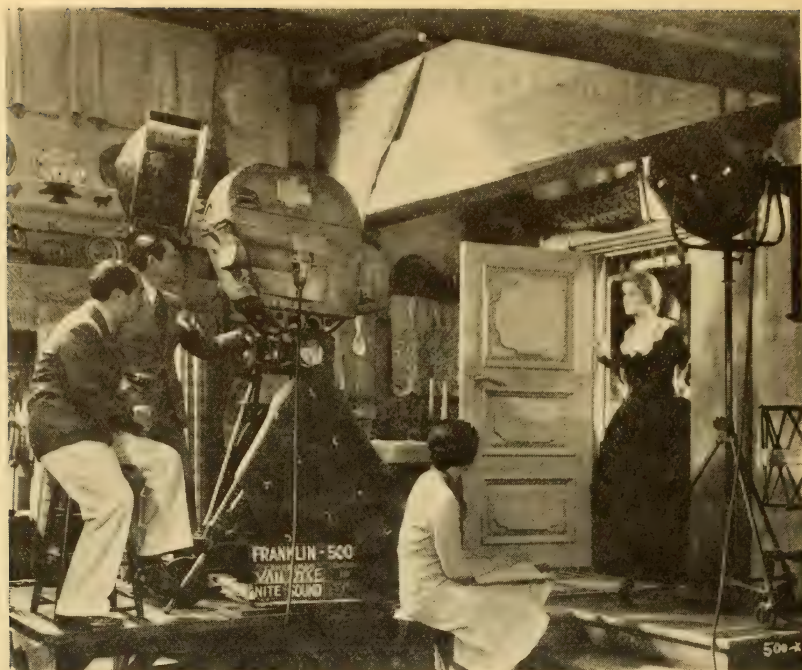
IN THE TRENCHES

Edgar MacGregor and Nick Grinde figure out some effective angles for the football scenes in "Good News." Here you see how by using a trench you may get unusual shots.



SHIP STUFF

Paramount cameramen had to turn sailors in the making of "Typhoon Bill." Here you see how they had to work for some of the scenes.



SHOOTING A STAR

An intimate glimpse of the making of a closeup of Grace Moore at the Metro-Goldwyn-Mayer studios. Note the sound-proof camera equipment.



AN UNUSUAL ANGLE

Here is a platform built so the cameraman can photograph even the soles of the diver's feet as they disappear in the water.

USEFUL FACTS
and
FORMULAE



TINTING AND TONING MOTION PICTURE FILM

IN THE production of motion pictures it is often desirable to vary the color of the film either by tinting or toning or by a combination of the two processes.

Tinting, as usually understood, consists in immersing the film in a solution of dye which colors the gelatin, causing the whole picture to have a uniform veil of color on the screen. In commercial production this effect is most frequently secured by the use of positive film coated upon a base of colored celluloid. A great variety of tints are commercially available in both nitrate and acetate stocks, in all widths from 16 mm. to 70 mm.

Toning consists in either wholly or partially replacing the silver image of the positive film by some colored compound, so that the clear portions or highlights of the image, which consist of plain gelatin, remain unaffected and colorless, but the remainder of the image is colored.

Combinations of tones and tints are possible, and produce many beautiful effects.

Tinting

When tinting with dye solutions, the dye colors the gelatine layer, whereas in the case of tinted base film, the film base itself is colored.

Success in tinting depends on the correct choice of dyes and the correct methods of their application.

Dyes are of two kinds, acid and basic, depending upon their chemical composition, acid dyes being alkali salts of organic acids, while basic dyes are the chlorides, sulphates, etc., of organic bases.

In view of the opposite nature of acid and basic dyes, it is obvious that, if several dyes are to be mixed one with another to produce intermediate tints, they must all be of the same class. Since the number of acid dyes are usually more stable to light, they are the most suitable for tinting.

The equipment necessary for systematic tinting or toning is essentially the same as that required for development, consisting of the usual tanks and racks, or small drums, or the usual processing machines. The drum system is not to be recommended for large-scale operations, though for individual use it is most efficient and economical. In any case it is advisable that the equipment used for this purpose be used for it exclusively, and, if possible, occupy a separate room to exclude any chance of dye particles settling on wet film or dropping in the developing, fixing, or rinsing tanks. Similarly it is important never to sift nor allow the dyes to be blown into the air when weighing them out, and the mixing rooms should hence be located as far as possible from those in which wet film is handled.

Racks and tanks used with each solution should be kept separate to prevent their contaminating the baths of other solutions.

Waterproofing of wooden racks can be accomplished either by impregnating the wood with paraffin wax or by treating with a nitro-

cellulose lacquer. Painting, varnishing, or treatment with wax solutions is ineffective.

The following American-made dyes are the most suitable for dye-tinting, and offer a range of nine standard tints. In the cases where alternative dyes are recommended, they may differ slightly in color, rate of bleeding, etc., and they are therefore not strictly interchangeable. On the screen, however, the difference between films dyed with alternative dyes is practically imperceptible.

TINT	DYE	MANUFACTURER
Cine Red	Amaranth 40-F.	National Aniline & Chemical Co., New York
	Azo Rubine	White Tar Aniline Corp., 56 Vesey St., New York
Cine Scarlet	Crocein Scarlet MOO	National Aniline & Chemical Co., New York
	Scarlet G. R.	Levinstein, 74 India St., Boston, Mass.
Cine Orange Red	Lake Scarlet R.	National Aniline & Chemical Co., New York
Cine Orange	Wool Orange GG.	National Aniline & Chemical Co., New York
Cine Yellow	Quinolin Yellow	National Aniline & Chemical Co., New York
	Wool Yellow Extra Conc.	National Aniline & Chemical Co., New York
Cine Light Green	Naphtol Green B Conc.	White Tar Aniline Corp., 56 Vesey St., New York
	Naphtol Green M.	National Aniline & Chemical Co., New York
Cine Green	Acid Green L.	National Aniline & Chemical Co., New York
	Fast Acid Green B.	National Aniline & Chemical Co., New York
Cine Blue	Direct Blue 6B	National Aniline & Chemical Co., New York
	Niagara Sky Blue	National Aniline & Chemical Co., New York
Cine Violet	Fast Wool Violet B.	National Aniline & Chemical Co., New York
	National Violet 2RD	National Aniline & Chemical Co., New York

The following formulas for tinting are suggested:

FOR USE AT 65° F. (18° C.)

TINT NO.	DYE	AVOIRDUPOIS	METRIC	TIME
1.	Cine Red	33 ounces	1000 grams	3 minutes
	Water to.....	50 gallons	200 liters	
2.	Cine Red	13 ounces	400 grams	3 minutes
	Water to.....	50 gallons	200 liters	
3.	Cine Scarlet	13 ounces	400 grams	3 minutes
	Water to.....	50 gallons	200 liters	
4.	Cine Orange-Red	13 ounces	400 grams	3 minutes
	Water to.....	50 gallons	200 liters	
5.	Cine Orange	6½ ounces	200 grams	3 minutes
	Cine Scarlet	145 grains	10 grams	
	Acetic Acid (glacial)	3¼ ounces	100 cc.	
	Water to.....	50 gallons	200 liters	
6.	Cine Orange	6½ ounces	200 grams	1 minute
	Acetic Acid (glacial)	3¼ ounces	100 cc.	
	Water to.....	50 gallons	200 liters	
7.	Cine Yellow	13 ounces	400 grams	1 minute
	Acetic Acid (glacial)	3¼ ounces	100 cc.	
	Water to.....	50 gallons	200 liters	
8.	Cine Light Green	26 ounces	800 grams	3 minutes
	Water to.....	50 gallons	200 liters	
9.	Cine Green	26 ounces	800 grams	3 minutes
	Water to.....	50 gallons	200 liters	
10.	Cine Blue	13 ounces	400 grams	3 minutes
	Water to.....	50 gallons	200 liters	
11.	Cine Blue	13 ounces	400 grams	1 minute
	Water to.....	50 gallons	200 liters	
12.	Cine Violet	13 ounces	400 grams	3 minutes
	Water to.....	50 gallons	200 liters	

The strength of the bath and the time of tinting can be adjusted to meet individual requirements.

The dyes should be mixed in glazed earthenware or enameled iron pails or crocks, using warm water when necessary. A separate wooden paddle should be used when mixing each dye, and washed thoroughly after using.

Dissolve the solid dyes in as small a volume of hot water as is possible, and filter through fine muslin. Pour hot water over any residue remaining, so that all the dye will be dissolved, and dilute the solution in the tank to the required volume at 65°F (18°C.)

The depth of the tint depends on the following factors:

1. *The Nature and Strength of the Dye Bath.*
2. *The Temperature of the Dye Bath.*

Although temperature has little effect on the rate of dying with the dyes recommended, when used without the addition of acid it is always advisable to work between 65° to 70°F. (18° to 21°C.) for uniform results.

3. *The Time of Dyeing.*

This is an important factor. The time of dyeing depends somewhat on the previous handlings of the film, as film fixed in a bath containing potassium or chrome alum dyes more quickly than film fixed in plain hypo and hardened with formalin.

Should the film for any reason be over-dyed, some of the dye may be removed by immediately washing for 10 to 15 minutes.

About 20,000 feet of film per 50 gallons of dye bath may be dyed. As the rate of dyeing slows down, the bath should be revived by adding a concentrated solution of the dye, and not by adding acid. When the bath becomes muddy, especially in warm weather, it should be renewed.

If uniform results are to be had, the film should never be passed through the projector before tinting or toning.

Toning

As distinct from *tinting*, a *toned* image consists of a colored image embedded in a layer of colorless gelatin, so that while the highlights are clear, the shadows are colored.

The coloring matter may consist of an inorganic colored compound (metallic salts) or a dye, or a mixture of both. The toned image is produced by wholly or partially replacing the silver image with one or more of these substances. The colors used in toning are necessarily very transparent, and therefore tones can only be judged by screen projection.

Of the various metal salts, uranium ferrocyanide (brown), iron ferrocynaide (blue), and silver sulphide are the most suitable.

Silver sulphide gives a blue-black tone when applied to a print of *normal* density, but when applied to a *thin* or *medium* print it gives a brown tone. It is commonly known as a *sepia* tone. It is applied by first bleaching in the following solution:

	(AVOIRDUPOIS)	(METRIC)	
A. Potassium Ferricyanide.....	8 ¹ / ₄	lbs.	4000 grams
Potassium Bromide.....	2	lbs. 1 oz.	1000 grams
Water to.....	50	gallons	200 liters

Bleach thoroughly in this until the image appears uniformly yellow on looking at the back of the film. Then wash for 5 minutes, and tone in:

B Sodium Sulphide (crystal).....	2 lbs. 1 oz.	1000 grams
Water to	50 gallons	200 liters

Temperature of baths: 65° to 70° F. (18° to 21° C.)

Time of Bleaching: Two to four minutes.

Time of Washing after Sulphiding: Ten to fifteen minutes.

Life of Baths: Bath A keeps well in the dark; solution B will keep almost indefinitely.

Uranium toning is a single-solution process, and consists of:

Uranyl (Uranium) Nitrate.....	16½ ounces	500 grams
Potassium Oxalate	16½ ounces	500 grams
Potassium Ferricyanide	6½ ounces	200 grams
Ammonium Alum	2½ lbs.	1200 grams
Hydrochloric Acid (10% sol.).....	1 quart	1000 cc.
Water to	50 gallons	200 liters

Mix in the order given. The solution obtained should be perfectly clear and pale yellow in color.

It is convenient to keep 10% stock solutions of the above, from which a new bath may be compounded quickly when needed. A 10% solution of Hydrochloric acid is one containing 10 parts by volume of the concentrated acid in 100 volumes of the final solution.

Temperature of Toning: 65° to 70° F. (18° to 21° C.)

Time of Toning: For maximum effect, 10 minutes, during which time the tone passes through a series of changes from brown to red. By withdrawing the film at any shorter interval, any intermediate tone desired can be obtained. As this bath intensifies the image considerably, the type of print used for these intermediate tones should be carefully adjusted to the time of immersion in the toning bath needed to secure that tone. This chart is a safe guide to work from:

NATURE OF PRINT	TIME OF TONING	COLOR
Normal	2 Minutes	Chocolate
Medium	5 minutes	Warm Brown
Thin	10 minutes	Reddish Brown

Time of Washing: Ten to fifteen minutes. In this time the highlights will become clear, though a thin yellowish-brownish veil may remain in the clear gelatin as a result of the intensification of minute traces of fog: this has no effect on projection. Washing should not be prolonged, especially if the water is inclined to be alkaline, as the toned image is soluble in alkali.

Life of Bath: Fifty gallons will tone about 5,000 feet of film, after which the rich tone tends to flatness. At this point the bath may be revived by adding acid to the extent of the original amount, after which a further 5,000 feet of film may be toned. After this stage the bath becomes exhausted rapidly, and should be thrown away.

Iron Tone (Blue):

Ammonium Persulphate	3¼ ounces	100 grams
Ferric Alum (ferric Ammonium Sulphate).....	8¼ ounces	250 grams
Oxalic Acid	1¼ lbs.	600 grams
Potassium Ferricyanide	6½ ounces	200 grams
Ammonium Alum	2 lbs. 1 ounce	1000 grams
Hydrochloric Acid (10% sol.)	6½ ounces	200 cc.
Water to	50 gallons	200 liters

The method of compounding this bath is very important. Each of the solid chemicals should be dissolved separately in a small quantity of warm water, the solutions allowed to cool, filtered into the tank strictly in the order given, and the whole diluted to the required volume. The bath should be a pale yellow color, and perfectly clear.

Time of Toning: Two to ten minutes at 70° F. (21° C.) The color of the image varies from a light bluish-grey for short time toning (about 3 minutes) to a deep blue for maximum immersion.

Time of Washing: Ten to fifteen minutes, until the highlights are clear. A very slight permanent yellow coloration of the clear gelatin usually occurs, but should be only just visible. It has no effect on projection. Washing should not be unduly prolonged.

Life of Bath: If acid is renewed to the extent of the original amount after toning each 5,000 feet, the bath is capable of toning 15,000 feet per 50 gallons of solution.

A very pleasing tone is obtained by first toning in the Uranium bath for about 3 minutes and then in the iron bath for about 2 minutes.

Dye Toning

As the number of suitable colored metallic compounds is rather limited, other methods of toning have also been evolved. Certain inorganic compounds have been found to have the peculiar property that when immersed in a solution of a basic dye the dye comes out of the solution and attaches itself to the compound. The dye is then said to be *mordanted*, and the inorganic compound is called a *mordant*. Silver ferrocyanide is a typical mordant. Therefore if a silver image is converted into a silver ferrocyanide image, and then immersed in a solution of a basic dye, a mordanted dye image is produced.

The Mordanting Bath

Uranyl (uranium) Nitrate	10½ ounces	320 grams
Oxalic Acid	5¼ ounces	160 grams
Potassium Ferrieyanide	5¼ ounces	160 grams
Water to	50 gallons	200 liters

The uranyl nitrate should be of good quality, and should not contain an excess of free nitric acid. First dissolve the chemicals separately in small quantity of water, then add the oxalic acid solution to the uranyl nitrate solution, and finally add the potassium ferrocyanide solution. After mixing, the bath should be light yellow and perfectly clear. Expose the solution to light as little as possible, as light causes the precipitation of a brown sludge of uranyl ferrocyanide.

Time of Mordanting: Immerse the film until a very slight chocolate colored tone is obtained. When the bath is new this will take from 1½ to 2 minutes, but as the bath ages, this time will be prolonged. If a concentrated stock solution of the mordanting bath is kept on hand a little of it may be added to revive the bath.

After mordanting 10,000 feet of film per 50 gallons, the bath should be thrown away.

The temperature of this bath should not be higher than 75° F (24°C.)

Time of Washing after Mordanting: Wash until the highlights are free from yellow stain, which usually takes from 10 to 15 minutes. Do not prolong the washing for more than 20 minutes, or some of the mordant will be washed out.

The Dye Bath

All the dyes used (except Methyl Violet and National Pink) are compounded according to the following formula:

Dye	1	ounce, 140 grains	40 grams
Acetic Acid (glacial)	3 1/4	ounces	100 cc.
Water to	50	gallons	200 liters

Thoroughly dissolve the dye in hot water, filter into the tank, and fill up the tank with cold water.

With Methyl Violet, use one-fourth the quantity of dye called for in the above formula. With National Pink, use six times the quantity of dye called for in the above formula.

The following dyes are suitable for dye toning:

National Pink B	Pink
Safranine A	Red
Chrysoidine 3R	Orange
Auramine	Yellow
Victoria Green	Green
Methylene Blue BB	Blue
Methyl Violet	Violet

Time of Dye Toning: Immerse in the dye bath for from 2 to 15 minutes, according to the color desired. A short immersion gives a slightly colored image, and prolonged immersion gives a strongly colored image.

Modifying Dye-Toned Images

If over-dyed, some of the dye can be removed by immersing in an 0.2% solution of concentrated ammonia and rinsing before drying.

If after dyeing 10 minutes the image does not mordant sufficient dye, wash thoroughly, re-immerses in the mordanting bath, wash again, and then place in the dye bath.

Intermediate dye-tones may be obtained by immersion in successive dye baths, or by mixing of the dye solutions.

By omitting the ammonium alum from the Iron toning formula, the half-tones of the toned film are white and the shadows blue: if this film is then immersed in any of the basic dye solutions given above, the dye is mordanted to the half-tones, while the shadows remain more or less blue. The best type of positive for this purpose is one of medium density.

Time of Toning: Tone until the shadows are deep blue.

Time of Washing: Ten to fifteen minutes.

Time of Dyeing: Immerse in the dye-bath until the desired depth of color in the half-tones is obtained: this may be from five to fifteen minutes.

Safranine gives *pink* half-tones.

Auramine gives *yellow* half-tones.

Chrysoidine gives *orange* half-tones.

Time of Washing After Dyeing: Until highlights are clear: from five to ten minutes.

Life of Bath: Same as that of the Iron toning formula.

Very pleasing effects may be had by combining tones and tints. The tints may be either chemical, or the result of the use of tinted-base film stock.

Tints and Tones for Amateur Use

All of the toning and tinting formula given above are suitable to amateur use on either reversal or normal positive films, of 16mm. or 9.5mm. standards. All that is necessary is to reduce the proportions of the solutions given to such as will make up the smaller quantities practical for individual use, and proceed according to the instructions given for professional use. However, a few special formulae and suggestions for amateur use are given here also.

For amateur use one method of getting tinted effects easily, and without altering the film, is by the use of special colored discs on the lens of the projector. Similarly, toned effects can be produced by the use of colored flood-lights played on the screen.

There are a number of photographic stains available commercially, which are suitable for tinting; and certain colored inks can also be used for the purpose, in suitable dilutions.

Any of the sepia toning compounds prepared for still photographic use, and sold ready-mixed, can also be used for cine toning. Similarly, the various other photographic tones—blue, red, green, etc.,—put up by Burroughs Wellcome & Co., Ltd., will also serve for this purpose.

The following solution is also excellent for blue toning:

Ferric Ammonium Citrate	100 grains
Potassium Ferricyanide	100 grains
Acetic Acid (glacial)	2 ounces
Water to	35 ounces

When the desired tone is reached, wash until the highlights are clear. This solution serves to intensify the image, so, if possible, when making scenes on reversal film for this treatment, overexpose them a trifle.

For tones ranging from warm black through purple and brown to brick red, the following is a useful formula:

(A)	Copper Sulphate	30 grains
	Potassium Citrate (neutral)	120 grains
	Water	10 ounces
(B)	Potassium Ferricyanide	120 grains
	Potassium Citrate (neutral)	10 ounces
	Water	25 grains

Mix A and B in equal parts immediately before using. The separate water. Films intended for this treatment should have a strong image, as there is a definite reducing action. Toning takes place very slowly.

Tones from warm sepia to red are obtainable with the following Uranium toner:

(A)	Uranium Nitrate	25	grains
	Acetic Acid (glacial)	$\frac{1}{2}$	ounce
	Distilled Water	18	ounces
(B)	Potassium Ferricyanide	25	grains
	Acetic Acid (glacial)	$\frac{1}{2}$	ounce
	Distilled Water	18	ounces

Mix A and B in equal parts immediately before using. The separate solutions keep indefinitely. If dry, the film to be toned should first be soaked in water before immersion in this bath, and, during immersion, be kept constantly on the move. When the desired tone is reached, the film should be removed to a stop-bath of 35 drops of acetic acid to 35 ounces of water. Washing should be done in still water, as running water is liable to wash out some of the color: the time of washing is until all trace of yellow is discharged. This is best used with rather thin images, as the action is somewhat of an intensifier.

Beautiful green tones are obtainable with this Vanadium Toner:

Vanadium Chloride (50% solution)	40	minims
Ferric Chloride	10	grains
Ferric Oxalate	10	grains
Potassium Ferricyanide	20	grains
Oxalic Acid (Saturated Solution)	$2\frac{1}{2}$	ounces
Water to	20	ounces

The oxalic acid solution is prepared by dissolving oxalic acid crystals in boiling water in the proportion of one ounce of water to every ounce of crystals. The solution should be allowed to cool. Add the ferric chloride and oxalate to the oxalic acid solution diluted in half the water, then add the ferricyanide, stirring well, and finally the vanadium. Tone until the color is slightly darker than required and then wash until the desired tone is reached. Any yellowish stain left in the highlights may be removed by a weak solution of ammonium sulpho-cyanide (2 grains per ounce of water). This toner has a considerable reducing action.

REVERSAL

Making Direct Positives

The making of direct positives, whether by the reversal-film process generally used by amateurs, or by converting an ordinary negative into a positive, consists in making a negative on a strip of film, developing it, and then printing that negative on the same strip and destroying the original negative chemically, but leaving the positive print to be developed, etc., in the usual way.

In 35mm. use, where regular reversal film is not available, either negative or positive film may be used, but where the light permits, positive is preferable, as it gives snappier results, although it is not corrected for color-values. As positive stock is far slower than negative, it can only be used under the best light conditions, and always with a much wider diaphragm opening than would be used with negative. It is not recommended for interiors. In any case, the exposure must be rather full.

The apparatus needed is a *solid* drum of metal or wood, painted with a dead black photographic enamel which must be resistant to the action of photographic chemicals. *A skeleton-type drum, with only ribs, cannot be used for reversal processing.*

Any high-contrast developer can be used. The following is a good formula:

Hydroquinone	1 ounce
Sodium Sulphite (Dry)	11 ounces
Sodium Carbonate (Dry)	7 ounces
Potassium Bromide	1 ounce
Water	1 gallon
Alcohol	1 pint

The alcohol may be omitted, but permits development at a higher temperature, giving greater contrast.

Development should be slow, by dim, red light, so as to give a snappy negative with pure whites and deep blacks. Be sure to develop fully.

Wash for five minutes or more, to remove all traces of developer.

At this stage, any swelling of the film should be taken up by tightening the film on the drum. Then the film should be exposed to a diffused, white light until the white portions of the film become visibly greyed.

The next step is to destroy the negative image by immersion in:

Water	1 gallon
Potassium Bichromate	1½ ounces
Nitric Acid	3 ounces

The film is immersed in this bath until the negative image has entirely disappeared, and only the creamy white of the remaining, undeveloped silver bromide is visible. After this, the film must be thoroughly washed, and the final, positive image then developed in the usual manner. This may be done in the same solution in which the negative was developed, or in some softer-working solution.

After this development, the print is fixed and washed in the usual manner.

Another set of formulae, especially intended for substandard reversal emulsions, are recommended by Messrs. Pathé for use with their Pathex system.

The formula for the first development is:

Paraphenylenediamine	150 grains
Sodium Sulphite (crystals)	1 ounce
Caustic Soda	150 grains
Potassium Bromide	60 grains
Phenosafranine (Solution 1:1000)	160 minims
Water	35 ounces

If *anhydrous* sulphite is used, only ½ ounce is needed. There are also several commercial desensitizers, such as "Desensol," etc., which can be readily substituted for the safranine solution required.

This developer must be used at temperatures between 60° and 65° F.

The developer should be filtered before use. Remember, too, that the caustic soda is bad for the eyes, so do not splash the developer.

In developing reversal film, the film should look almost opaque when the development is finished, and the black portions of the negative should appear of almost equal density from either side of the film. The following table will be useful in timing the development:

If the first signs of image appear in:	Develop for
Up to 20 seconds	5 to 8 minutes
30 seconds	10 minutes
40 seconds	12 minutes
1 minute	15 minutes
1¼ to 1½ minutes	20 to 25 minutes

Reversion is in this case carried out chemically, by use of the following reversion bath:

Potassium Permanganate	30 grains
Sulphuric Acid	170 minims
Water	35 ounces

The acid should be added last in a slow stream, stirring the while. Sodium Bisulphate (380 grains) may be substituted for the acid, but is not so effective.

In reversion the negative is dissolved away and the film takes on a red color. This normally takes from seven to ten minutes, but should in any case be continued until all of the black image is dissolved. If the amateur has both orange and red lights on his dark-room lamp, the red one may be removed after the film has been five minutes in this bath.

After reversion the film is washed until it becomes a clear yellow—usually about seven minutes. The remaining operations may be carried out in white light.

The next step is bleaching, by the following formula:

Sodium Sulphite (crystals)	150 grains
Sulphuric Acid	35 minims
Water	35 ounces

Immerse the film in this until the parts formerly densest become quite transparent. If there are found to be dark spots on the film, reversion is not complete: rinse the film thoroughly and return it to the reversion bath. Then wash, and bleach again.

The final step is darkening: this is done in a solution prepared by adding 150 grains of Sodium Hydrosulphite (NOT *hyposulphite*) to the bleaching bath. The film is placed in this, and the image steadily darkens until a good, brownish-black positive is produced. It is important that the Sodium Hydrosulphite be perfectly fresh: otherwise the image may not darken sufficiently, or may turn an unsatisfactory sepia tone.

After darkening, the film should be thoroughly washed in running water—at least 15 minutes—and then dried. Each of these solutions is sufficient for about 30 feet of substandard film, although the developer will last for about 90 feet. The quantities given here are those intended for use in the tanks made by the Pathex people in Europe, which hold 26 feet of film (one full Pathex charger). They are not as yet available in America, but may be had either from MM. Pathé-Enseignement, 20 bis rue La Fayette, Paris, 9e, France, or from Pathescope, Ltd., 5 Lisle Street, London, W.C. 2, England. The solutions recommended can, of course, be made up

in any larger quantity for use in larger tanks. Incidentally, the chemical type of reversion does not require a solid drum developing system.

With regard to the processing of reversal film by individual amateurs, most of the manufacturers state that while the methods outlined above will work with their products, they do not recommend individual processing, as an individual is rarely equipped to exercise the same exact control of all operations that the regular processing stations do. If an individual feels it is necessary to process his own film, the manufacturers point out that far more satisfactory results can be obtained by developing the film (reversal or otherwise) as a *negative* and subsequently making prints from it.

MOTION PICTURE DEVELOPER

(Negative or Positive Film)

	Avoirdupois	Metric
Water (about 125° F.) (52° C.)	64 ounces	2.0 liters
Elon	17 grains	1.2 grams
Sodium sulphite (E. K. Co.)	5¼ ounces	160.0 grams
Hydroquinone	350 grains	24.0 grams
Sodium carbonate (E. K. Co.)	2½ ounces	75.0 grams
Potassium bromide	50 grains	3.6 grams
Citric acid	40 grains	2.8 grams
Potassium metabisulphate	85 grains	6.0 grams
Cold water to make	1 gallon	4.0 liters

Average time of development 7 to 15 minutes at 65° F. (18° C.)

Fine Grain Developers for Motion Picture Negative Film

The following formulas have been found to give finer grained images than any other commercially used developer and are recommended for the development of ordinary and panchromatic negative film.

With use, these developers may become slightly muddy but this is due to a suspension of colloidal silver which is likely to form and which is harmless and may be ignored. The tank usually becomes coated with a thin white deposit of silver but this does no harm.

	Formula D-76	A	B
Elon	120 grains	120 grains	160 grains
Sodium Sulphite (E.K.Co.)	14 ounces	14 ounces	14 ounces
Hydroquinone	300 grains	160 grains	160 grains
Borax	120 grains	120 grains	120 grains
Water	128 ounces	1 Gallon	128 ounces

Temperature of developer 65° F.

"A" developer will give a little more snap in quality—while the "B" developer will give a softer quality negative.

Directions for Mixing: Owing to the high concentration of sulphite in the formulas, it is somewhat difficult to dissolve all the chemicals unless directions are followed carefully.

First dissolve the Elon in a small volume of water (about 125° F.) and add the solution to the tank. Then dissolve approximately one quarter of the sulphite separately in hot water (about 160° F.) and add the hydroquinone with stirring until completely dissolved. Add this solution to the tank. Then dissolve the remainder of the sulphite in hot water (about 160° F.) add the borax, and when dissolved pour the entire solution into the tank and dilute to the required volume with cold water.

The development time varies with the number of feet which have been processed but the average time for a fresh bath is from 10 to 15 minutes at 65° F. If a slower working developer is required the quantity of Elon, hydroquinone and borax should be reduced. To obtain a faster working developer, increase the quantities of these chemicals.

The life of the developers is practically the same as that of the usual Elon-pyro motion picture developer in general use. An idea of the increase in development time with use may be gained from the fact that after 25,000 feet of film have been processed per 300 gallons of developer the development time is practically doubled.

The developers may be revived once or twice during their life by the addition of half the quantity of borax originally used in the formula.

These developers are somewhat sensitive to the effect of sodium bromide produced by the conversion of the silver bromide in the processed film to metallic silver. A comparatively fresh solution is therefore necessary for developing extreme underexposures. With average studio exposures, however, excellent negatives can be obtained even with the partially exhausted developer.

MOTION PICTURE FIXING BATH

	<i>Avoirdupois</i>	<i>Metric</i>
Water	1 gallon	4.0 liters
Hypo	2 pounds	960.0 grams

When thoroughly dissolved, add the following cool hardener solution slowly stirring to the cool hypo solution.

	<i>Avoirdupois</i>	<i>Metric</i>
Water	4 ounces	128.0 cc.
Sodium sulphite (E. K. Co.)	175 grains	12.0 grams
*Acetic acid (28% pure) (E. K. Co.)	2¼ ounces	72.0 cc.
Powdered potassium alum	350 grains	24.0 grams

*To make 28% acetic acid from glacial acetic acid, dilute three parts of glacial acid with eight parts of water.

To make up the hardener dissolve the chemicals in the order given above. The sodium sulphite should be dissolved completely before adding the acetic acid. After the sulphite acid solution has been mixed thoroughly, add the potassium alum with constant stirring. If the hypo is not thoroughly dissolved before adding the hardener a precipitate of sulphur is likely to form.

FINE GRAIN NEGATIVE DEVELOPER

For Motion Pictures

(Elon-Hydroquinone-Borax)

	<i>Avoirdupois</i>	<i>Metric</i>
Elon	115 grains	8.0 grams
Sodium sulphite (E. K. Co.)	13¼ ounces	400.0 grams
Hydroquinone	290 grains	20.0 grams
Borax	115 grains	8.0 grams
Water to make	1 gallon	4.0 liters

Directions for Mixing: Dissolve the elon in a small volume of water (at about 125° F) (52° C.) and add the solution to the tank. Then dissolve approximately one-quarter of the sulphite separately in hot water (at about 160° F.) (71° C.), add the hydroquinone with stirring until completely dissolved. Then add this solution to the tank. Now dissolve the remainder of the sulphite in hot water (about 160° F.) (71° C.), add the borax and when dissolved, pour the entire solution into the tank. Dilute to the required volume with cold water.

Time of development is 10 to 20 minutes at 65° F. (18° C.)

NEGATIVE MOTION PICTURE DEVELOPER

(Elon-Hydroquinone)

	<i>Avoirdupois</i>	<i>Metric</i>
Elon	115 grains	8.0 grams
Sodium sulphite (E. K. Co.)	2½ ounces	75.0 grams
Hydroquinone	29 grains	2.0 grams
Sodium carbonate (E. K. Co.)	1¾ ounces	50.0 grams
Potassium bromide	43 grains	3.0 grams
Water to make	1 gallon	4.0 liters

Time of development 6 to 12 minutes at 65° F. (18° C.)

MOTION PICTURE DEVELOPER

Negative or Positive

GLYCIN

(Hubl's Formula)

STOCK SOLUTION

Hot Water	1 gallon
Sodium Sulphite	5 lbs.

DISSOLVE AND ADD:

Glycin	2 lbs.
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DISSOLVE AND ADD SLOWLY:

Potassium Carbonate	10 lbs.
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For Use:

AS A NEGATIVE DEVELOPER: Use 1 part of the Stock Solution to 60 of water.

AS A POSITIVE DEVELOPER: Use 1 part of the Stock Solution to 15 or 30 of water.

POSITIVE DEVELOPER

Elon.....	7 ounces
Sodium Sulphite.....	30 lbs.
Hydroquinone.....	4 lbs.
Potassium Metabisulphite.....	1 lb.
Sodium Carbonate.....	15 lbs.
Potassium Bromide.....	10 ounces
Water to.....	150 gallons

Time of Development:

For normal contrast, $3\frac{1}{2}$ to 4 minutes at 65°F.

INTENSIFIERS.

SILVER CYANIDE INTENSIFIER.

Especially suited for cartoon and title work where extreme contrast is desired
Solution A.

Potassium Bromide.....	1 lb.
Bichloride of Mercury.....	1 lb.
Water.....	10 gallons

Solution B.

Pure Cyanide of Potassium.....	1 lb.
Nitrate of Silver.....	1 lb.
Water.....	10 gallons

Place the film in Solution A until the image has been bleached clear through to the back of the film, then rinse well and transfer to Solution B. One immersion gives a heavy degree of intensification, but if a greater degree is required, the operation may be repeated.

BOTH SOLUTIONS ARE HIGHLY POISONOUS
MERCURIC IODIDE INTENSIFIER.

This formula has the faculty of reducing contrasts in addition to intensifying the general image. HIGHLY POISONOUS.

Water.....	100 gallons.
Sodium Sulphite (anhydrous).....	83 lbs.
Iodide of mercury.....	$8\frac{1}{4}$ lbs.

Immerse the film in this solution until the desired strength has been obtained. Then wash in running water for at least 15 minutes, place in the regular developer for 3 to 5 minutes. Then wash again for 30 minutes.

REDUCERS.

PERSULPHATE REDUCER.

Reduces the dense portions of negatives without materially changing the high-lights or thinner portions of the image.

Place film (wet) in solution No. 1:

Ammonium Persulphate.....	$33\frac{1}{4}$ lbs.
Water.....	100 gallons.

As soon as the right density has been obtained, place the film in the stop-bath, solution No. 2:

Sodium Sulphite.....	10 lbs.
Water.....	100 gallons.

After this the film should be washed in running water for 15 to 20 minutes, then dried as usual.

FERRICHLORIDE REDUCER.

Reduces high-lights faster than shadows, thereby overcoming extreme contrast.

Ferrichloride.....	1 dr.
Hydrochloric Acid.....	.2 dr.
Water.....	10 ounces

Negative to be reduced must first be washed until all trace of hypo is removed. Then immerse in the reducer for a minute or so; on removal from this bath no action will be apparent, but on immersing the film in a freshly mixed hypo bath, reduction will take place very quickly. The operation should be watched carefully, and stopped a little short of completion, when the negative should be washed and dried as usual.

FERRICYANIDE (FARMER'S) REDUCER.

Reduces the shadows more than the high-lights. Must be freshly prepared as it deteriorates rapidly.

Add to the desired quantity of *fresh* hypo solution enough of a saturated solution of Potassium Ferricyanide to make it lemon colored. If the color is too deep, verging on orange, reduction will be too rapid to be controlled. When reduction has proceeded far enough, wash the film quickly to prevent further action.

HANDY EMERGENCY WEIGHTS

Dime.....	40 grs.
Cent.....	50 grs.
Nickel.....	80 grs.
Quarter-Dollar.....	100 grs.
Half-Dollar.....	200 grs.
Dollar.....	400 grs.

FLAT BLACK VARNISH FOR BLACKING INSIDE OF CAMERA, ETC.

Alcohol.....	8 ounces.
Lamp Black.....	2 ounces.
Shellac.....	1 ounce.

Dissolve shellac in alcohol, then add lamp black, and mix thoroughly.

FLAT BLACK FOR METALLIC PARTS—SHUTTERS, DIAPHRAGMS, Etc

Nitric Acid.....	4 ounces.
Copper Wire.....	$\frac{1}{4}$ ounce.

Dissolve the copper wire in the nitric acid and then add slowly $\frac{1}{4}$ ounces of water.

The parts to be blackened must be thoroughly cleaned, then heated and immersed in the acid bath after which they are taken out and brushed off or until the article shows a rich blue-black.

INK FOR WRITING ON GLASS

WHITE: Mix 1 part Chinese White (water-color pigment) or Barium Sulphate with 3 or 4 parts Sodium Silicate Solution (water glass). The sodium silicate solution should have the consistency of glycerin.

BLACK: Mix 1 part liquid Chinese Ink (or Higgins "Eternal" or other carbon ink) with 2 parts Sodium Silicate Solution.

Apply with ordinary steel pen. Ink will dry in 15 minutes. It is waterproof, but may be removed by scraping with a knife.

DEAD BLACK FOR WOOD

Borax.....	30 grs.	8 grams.
Glycerin.....	30 minims	8 cc.
Shellac.....	60 grs.	16 grams.
Water.....	8 ounces	1000 cc.

Boil till dissolved, and add:

Nigrosine, W. S.....	60 grs.	16 grams.
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Or paint the wood first with:

Cupric Chloride.....	75 grs.	75 grams.
Potassium Bichromate.....	75 ounces	75 grams.
Water.....	$2\frac{1}{4}$ grs.	1000 cc.

As soon as the surface dries, apply:

Aniline Hydrochlorate.....	150 grs.	150 grams.
Water.....	$2\frac{1}{4}$ ounces	1000 cc.

Wipe off any yellow powder that forms. Repeat the process until black enough. Then rub over with boiled linseed oil.

WATERPROOFING WOOD

Asphalt.....	4 ounces	400 grams.
Pure Rubber.....	30 grs.	6 grams.
Mineral Naphtha.....	10 ounces	1000 cc.

Apply with a stiff brush. Give three successive coats, allowing each to dry thoroughly. The vapor from this solution is highly inflammable.

POLISH FOR CAMERAS, WOODWORK, ETC.

Linseed Oil	20	ounces	400 cc.
Spirits of Camphor	2	ounces	40 cc.
Vinegar	4	ounces	80 cc.
Butter of Antimony	1	ounce	20 grams.
Liquid Ammonia	$\frac{1}{4}$	ounce	5 cc.
Water	$\frac{1}{4}$	ounce	5 cc.

Apply very sparingly with a bit of old flannel, and rub off thoroughly with soft rags.

BLACKENING BRASS WORK.

A. Copper Nitrate	200	grs.	450 grams.
Water	1	ounce	1000 cc.
B. Silver Nitrate	200	grs.	450 grams.
Water	1	ounce	1000 cc.

Mix A and B, and place the brass work (perfectly cleaned) in the solution for a few moments, heating on removal.

VARNISH FOR BRASS WORK

Celluloid	10	grs.	4 grams.
Amyl Alcohol	$\frac{1}{2}$	ounce	100 cc.
Acetone	$\frac{1}{2}$	ounce	100 cc.

Commercial "cold lacquer" may also be used for this purpose.

TO BLACKEN ALUMINUM

Clean thoroughly with fine emery powder, wash well, and immerse in:

Ferrous Sulphate	1	ounce	80 grams.
White Arsenic	1	ounce	80 grams.
Hydrochloric Acid	12	ounces	1000 cc.

Dissolve and add:

Water	12	ounces	1000 cc.
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When the color is deep enough, dry off with fine sawdust, and lacquer.

SILVERING MIRRORS.

A. Silver Nitrate	175	grs.	40 grams.
Distilled Water	10	ounce	1000 cc.
B. Ammonium Nitrate	262	ounces	60 grams.
Distilled Water	10	ounce	1000 cc.
C. Pure Caustic Potash	1	ounce	100 grams.
Distilled Water	10	ounce	1000 cc.
D. Pure Sugar Candy	$\frac{1}{2}$	ounce	100 grams.
Distilled Water	5	ounce	1000 cc.

Dissolve and add:

Tartaric Acid	50	grs.	23 grams.
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Boil in flash for 10 minutes, and when cool add:

Alcohol	1	ounce	200 cc.
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For use, take equal parts of A and B. Mix together also equal parts of C and D—mixing in another measure. Then mix both of these two mixtures together in the silvering vessel, and suspend the mirror *face downward* in the solution.

THERMOMETRIC TABLES

For converting temperature readings by one system into those of any other system, these rules will be found useful.

Centigrade (Celsius) to Fahrenheit:

Multiply degrees C. by 9, divide by 5, then add 32.

Centigrade to Réaumur:

Multiply degrees C. by 4 and divide by 5.

Fahrenheit to Centigrade (Celsius):

Subtract 32 from Fahrenheit reading; multiply by 5 and divide by 9.

Fahrenheit to Réaumur:

Subtract 32, divide by 9, multiply by 4.

Réaumur to Centigrade (Celsius):

Multiply by 5 and divide by 4.

Réaumur to Fahrenheit:

Multiply by 9, divide by 4, add 32.

TABLE OF CHEMICAL SOLUBILITIES

THE following table will serve as a guide when preparing stock solutions of photographic chemicals. As a solution is likely to become cooled in winter to a temperature approximately 40° F., it is not advisable to prepare a stock solution stronger than is indicated by the solubility of the chemical at this temperature.

Substance	Ounces of chemical in 100 ozs. (fluid) of saturated solution at	
	40° F. (4.4° C.)	70° F. (21.1° C.)
Acid, acetic (any strength)	mixes in all proportions	
Acid, citric	78	88
Acid, oxalic	7½	14½
Acid, tartaric (dextro)	73	78
Acrol or amidol (see diaminophenol hydrochloride)		
Alum, ammonium	6¼	15½
Alum, iron	48	59
Alum, potassium	6¼	11½
Alum, potassium chrome	15½	20½
Amidol or acrol (see diaminophenol hydrochloride)		
Ammonia solution	mixes in all proportions	
Ammonium bromide	52	57
Ammonium carbonate	26	31
Ammonium chloride	26	30
Ammonium iodide	104	109
Ammonium oxalate	2¾	5¼
Ammonium persulphate	52	62
Ammonium thiocyanate or ammonium sulphocyanide	62	73
Ammonium thiosulphate, anhydrous	83	88
Borax (sodium tetroborate)	2½	7¼
Caustic potash (see potassium hydroxide)		
Copper sulphate, crystal	26	31
Diaminophenol hydrochloride (acrol or amidol)	20½	26
Elon (monomethyl para-amino phenol sulphate)		
Ferrous sulphate	5¼	8¼
Formalin	29	41
Hydroquinone	mixes in all proportions	
Hypo (see sodium thiosulphate)	4¼	6¼
Kodolon (see para-aminophenol oxalate)		
Lead acetate	31	47
Mercuric chloride	4	6¼
Para-aminophenol oxalate (kodolon)	1¼	2½
Potassium bichromate	6¾	14½
Potassium bromide	50	56
Potassium carbonate, anhydrous	83	85
Potassium chloride	26	31
Potassium citrate	93	104
Potassium cyanide	46	52
Potassium ferricyanide	30	36
Potassium ferrocyanide	17½	26
Potassium hydroxide (caustic potash)	78	83
Potassium iodide	99	104
Potassium metabisulphate	47	57
Potassium oxalate	29	36½
Potassium permanganate	3¼	6¾
Pyrogallol (pyro)	36	57
Silver nitrate	109	135
Sodium acetate, anhydrous	31	36
Sodium acetate, crystal (trihydrate)	52	62
Sodium bicarbonate	7¼	9¼
Sodium bisulphate	52	52
Sodium bromide	67	73
Sodium carbonate, anhydrous	10¼	24
Sodium carbonate, crystal	29	65
Sodium chloride	31	31
Sodium hydroxide (caustic soda)	50	83
Sodium phosphate, dibasic crystal	6½	24
Sodium sulphate, anhydrous	5¼	20½
Sodium sulphate, crystal	10¼	41
Sodium sulphide, fused	13½	17½
Sodium sulphide, crystal	36¾	47
Sodium sulphite, anhydrous	17½	28
Sodium tetraborate (see borax)		
Sodium thiosulphate, (hypo) crystal	73	93
Uranyl (uranium) nitrate	114	130

PICTURE SIZES OBTAINED WITH PROJECTION LENSES

Focal Length of Lens in Inches	Distance in Feet From Screen													
	8	10	12	16	20	25	32	36	40	45	50	64	75	100
	Size of Picture (Feet and Decimals) (First figure shows width, second figure shows height)													
$\frac{3}{4}$	4.10 3.04	5.13 3.80												
1	3.08 2.28	3.85 2.85	4.62 3.42	6.16 4.56	7.70 5.70	9.63 7.13								
$1\frac{1}{2}$	2.05 1.52	2.57 1.90	3.08 2.28	4.11 3.04	5.13 3.80	6.42 4.75	8.21 6.08	9.24 6.84						
2	1.54 1.14	1.93 1.43	2.31 1.71	3.08 2.28	3.85 2.85	4.81 3.56	6.16 4.56	6.93 5.13	7.70 5.70	8.65 6.41	9.53 7.13			
$2\frac{1}{2}$	1.23 .91	1.54 1.14	1.85 1.37	2.46 1.83	3.03 2.28	3.85 2.85	4.93 3.65	5.54 4.10	6.16 4.56	6.93 5.13	7.70 5.70	9.86 7.30		
3		1.23 .95	1.54 1.14	2.05 1.52	2.57 1.90	3.21 2.38	4.11 3.04	4.62 3.42	5.13 3.80	5.77 4.28	6.42 4.75	8.21 6.08	9.63 7.13	
$3\frac{1}{2}$		1.10 .81	1.32 .98	1.76 1.30	2.20 1.63	2.75 2.04	3.52 2.60	3.96 2.93	4.40 3.26	4.95 3.66	5.50 4.07	7.04 5.21	8.25 6.11	11.00 8.14
4			1.16 .86	1.34 1.14	1.94 1.43	2.41 1.73	3.00 2.28	3.47 2.57	3.85 2.85	4.35 3.21	4.82 3.57	6.16 4.56	7.22 5.35	9.63 7.13

TABLE OF HYPERFOCAL DISTANCES

FOLLOWING will be found a table of hyperfocal distances, showing the distance at which critical sharpness is obtained for each diaphragm opening when the lens is focused at infinity. All objects at the distances shown and beyond will be in focus. You will notice that the telephoto lens

is not scaled clear up to the infinity mark. For subjects between the highest footage mark on lens focusing scale and the hyperfocal distance for diaphragm stop being used, your estimate of proper setting between highest footage on lens and infinity mark will give sharp focusing.

Focal Length	F1.8	F2.7	F3.3	F3.5	F4	F4.5	F5.5	F6.3	F8	F11	F16	F22	F32
25 m/m	22'	15'	12'	11 $\frac{1}{2}$ '	10'	9'	7'	6'	5'	4'	2 $\frac{1}{2}$ '		
35 m/m	44'	29'	24'	22 $\frac{1}{2}$ '	20'	17 $\frac{1}{2}$ '	14 $\frac{1}{2}$ '	12 $\frac{1}{2}$ '	10'	7'	5'		
3"		139'	114'	107'	94'	83'	68'	60'	47'	34'	23'	17'	12'
Telephoto 3 $\frac{3}{4}$ "			178'	167'	146'	130'	107'	93'	73'	53'	36'	26'	18'
Telephoto 4"				190'	167'	148'	121'	106'	83'	61'	42'	30'	21'
Telephoto 6"					375'	333'	273'	238'	188'	136'	94'	68'	47'

AMATEUR CINE PROJECTION.

PROJECTION DISTANCES FROM PROJECTION LENS TO SCREEN.

Screen Size.	Distance required with		
	1 inch Lens.	1 $\frac{3}{8}$ inch Lens.	2 inch Lens.
10" X 13"	3 ft.	4 ft.	6 ft.
16 $\frac{1}{2}$ " X 22"	5 ft.	6 $\frac{3}{4}$ ft.	10 ft.
22" X 30"	6 $\frac{3}{4}$ ft.	9 ft.	13 $\frac{1}{2}$ ft.
30" X 40"	9 ft.	12 ft.	18 ft.
39" X 52"	11 $\frac{1}{2}$ ft.	15 $\frac{3}{4}$ ft.	23 ft.

DIAPHRAGM NUMBERS.

EXPOSURES AT DIFFERENT APERTURES.

F. Numbers.....	1·8	2	2·2	2·5	2·7	2·9	3·16	3·4
Rel. Exposure Required—								
Fractions.....	2/3	3/4	1	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{3}{4}$	2	2 $\frac{1}{3}$
Decimal.....	0·83	1	1·33	1·66	2	2·33	2·66	3
Seconds.....	1/1200	1/1000	1/750	1/600	1/500	1/428	1/375	1/325

F. Numbers.....	3·5	3·9	4·5	5	5·6	6	6·3	8
Rel. Exposure—								
Fractions.....	2 $\frac{1}{2}$	3	4	5	6	7	8	12
Decimal.....	3·33	4	5·3	6·66	8	9·3	10·6	16
Seconds.....	1/300	1/250	1/190	1/150	1/125	1/100	1/95	1/60

The above table gives the relative exposures with lens apertures.

The Fraction line gives a series of F/Nos. each requiring double the exposure of the preceding one. This series is F/2·2, 3·16, 4·5, 6·3. The decimal line gives a similar series, beginning with f/2, viz., F/2, 2·7, 4, 5·6, 8. The last line gives the relative Speed of any lens, in comparison with another lens of different aperture.

EQUIVALENT F/- AND UNIFORM SYSTEM NUMBERS

Rel. Exposure Req'd.	1	2	4	8	16	32	64	128
F. Numbers.....	4	5·6	8	11·3	16	22·6	32	45·2
U.S. Numbers.....	1	2	4	8	16	32	64	128

Among Continental opticians at the present time it is usual to adopt a different series of F/Nos. each requiring double the exposure of the preceding one. This series is:—

F/Number.....	3·16	4·5	6·3	9	12·5	18	25·3	36
---------------	------	-----	-----	---	------	----	------	----

NOTE.—Most lenses are now marked with the F/numbers, according to one or other of the above two series, although the U.S. numbers are used on Kodak lenses. Also the actual diameter of the diaphragm aperture in millimetres is marked on some Continental lenses.

TABLE OF DISTANCES FOR LANTERN PROJECTION.
 DISTANCE OF PROJECTION LENS FROM SCREEN, MASK BEING THREE INCHES.

Foci	4½		5	5½	6	7	8	9	10	11	12	14	15	16
Disc.	ft.	in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft.	ft. in.	ft. in.	ft. in.
5	7	10½	8 9	9 7½	10 6	12 3	14 0	15 9	17 6	19 3	21	24 6	26 3	28 0
6	9	4½	10 5	11 5½	12 6	14 7	16 8	18 9	20 10	22 11	25	29 2	31 3	33 4
7	10	10½	12 1	13 3½	14 6	16 11	19 4	21 9	24 2	26 7	29	33 10	36 3	38 8
8	12	4½	13 9	15 1½	16 6	19 3	22 0	24 9	27 6	30 3	33	38 6	41 3	44 0
9	13	10½	15 5	16 11½	18 6	21 7	24 8	27 9	30 10	33 11	37	43 2	46 3	49 4
10	15	4½	17 1	18 9½	20 6	23 11	27 4	30 9	34 2	37 7	41	47 10	51 3	54 8
11	16	10½	18 9	20 7½	22 6	26 3	30 0	33 9	37 6	41 3	45	52 6	56 3	60 0
12	18	4½	20 5	22 5½	24 6	28 7	32 8	36 9	40 10	44 11	49	57 2	61 3	65 4
13	10	10½	22 1	24 3½	26 6	30 11	35 4	39 9	44 2	48 7	53	61 10	66 3	70 8
14	21	4½	23 9	26 1½	28 6	33 3	38 0	42 9	47 6	52 3	57	66 6	71 3	76 0
15	22	10½	25 5	27 11½	30 6	35 7	40 8	45 9	50 10	55 11	61	71 2	76 3	81 4
16	24	4½	27 1	29 9½	32 6	37 11	43 4	48 9	54 2	59 7	65	75 10	81 3	86 8
18	27	4½	30 5	33 5½	36 6	42 7	48 8	54 9	60 10	66 11	73	85 2	91 3	97 4
20	30	4½	33 9	37 1½	40 6	47 3	54 0	60 9	67 6	74 3	81	94 6	101 3	108 0
25	37	10½	42 1	46 3½	50 6	58 11	67 4	75 9	84 2	92 7	101	117 10	126 3	134 8
30	45	4½	50 5	55 5½	60 6	70 7	80 8	90 9	100 10	110 11	121	141 2	151 3	161 4
35	52	10½	58 9	64 7½	70 6	82 3	94 0	105 9	117 6	129 3	141	164 6	176 3	188 0
40	60	4½	67 1	73 9½	80 6	93 11	107 4	120 9	134 2	147 7	161	187 10	201 3	214 8

PROCESSING REVERSIBLE CINE-FILM

M. JACQUES HENRI-ROBERT, president of the Amateur Cinematographic section of the French Photographic Society, has recommended the following procedure for reversal of amateur cine film.

The first developer is a paraphenylene diamine developer made up as follows:

Paraphenylene diamine	10 gms.	90 grs.
Soda sulphite, anhyd.	45 gms.	400 grs.
Caustic soda	10 gms.	90 grs.
Potass. bromide	4 gms.	35 grs.
Phenosafranine, 1 : 1,000 sol.	50 c.c.s.	1 oz.
Water	1,000 c.c.s.	20 ozs.

The paraphenylene diamine, finely powdered, is first dissolved in very hot water and the sulphite then added. The other constituents are dissolved in the cooled solution. Before use, the developer is filtered through glass wool.

At 65° F. a well-exposed film needs 15 mins. development, and this time should not be varied by more than 5 mins. The developer may be used for several films in succession. The developed film is well washed—for at least five minutes in running water—before reversal.

The reversal bath is made up from the following stock solution:

Potass. permanganate	2 gms.	18 grs.
Water	1,000 c.c.s.	20 ozs.

To make the working bath, add to the above bath 80 c.c.s. (1½ ozs.) of dilute sulphuric acid, made by adding 10 parts of the concentrated acid to 100 parts of water.

When the film has been immersed in this working bath for about a minute, white light may be switched on. The film must remain until all the black silver deposit has disappeared, the normal time of immersion being 7 to 8 minutes. It is then washed for five minutes in running water. This bleaching bath should not be used again.

For clearing, the film is placed for five minutes in the following bath, to be used once only:

Sodium metabisulphite, anhyd.	200 gms.	4 ozs.
Water	1,000 c.c.s.	20 ozs.

The cleared film is then re-developed in a freshly made developer consisting of:

Sodium bisulphite lye	50 c.c.s.	1 oz.
Sodium hydrosulphite	10 gms.	90 grs.
Water	1,000 c.c.s.	20 ozs.

The hydrosulphite used in this developer, it should be noted, is an entirely different compound from the hyposulphite commonly used.

Re-development takes from 10 to 20 minutes and must be done under the strongest illumination available, e.g., full daylight. This solution should be used only once.

The re-developed film is washed for fifteen minutes in running water before drying, in the usual way.

A positive film which is too dense may be reduced by treatment in a very weak solution of acid permanganate, viz.:

Potass. permanganate, 1 : 500 solution	50 c.c.s.	1 oz.
Diluted sulphuric acid, as given above	5 c.c.s.	50 mins.
Water	1,000 c.c.s.	20 ozs.

After reduction the film is given a brief rinse, is fixed in an acid fixing bath, and is then washed for half an hour.

The persulphate reducer may also be employed.

The film may best be intensified with the chromium intensifier. The silver intensifier is not at all suitable. Toning, tinting and mordant dye-toning may be carried out just as in the case of films printed from negatives.

B.J., 1930, March 28, pp. 180-181.

LENSES FOR PORTRAIT STUDIOS

Focal Lengths of Lenses For Studios of Various Lengths

THE following table shows the focus of lens which is suitable for comfortable working in studios of various lengths. In each case it is assumed that 5 ft. of the length will be taken up by camera, operator, sitter and background. The figures in column 1 are the full run of the studio, including this 5 ft. In the case of the short studios the focal lengths are about the longest which can be used: in the case of the longer studios somewhat greater focal lengths might be used, but the lenses directed in the table are about the best for general work.

Length of Studio. Feet.	C.D.V. full length. Inches.	C.D.V. half length and Cabinet full length. Inches.	C.D.V. head. Cabinet half length. Inches.	Cabinet head and Boudoir full length. Inches.	Boudoir half length. Panel full length. Inches.	Boudoir head. Panel half length. Inches.
12	4*	6½*	8½	9	12*	14
14	4¾*	7½*	9	10*	13*	16
16	5¾	8½	10	10½	16	18
18	6	8½	10½	10½	16	18
20	6	10	10½	12	18	20
22	7	10½	12	14	22	22
24	8½	12	14	16	24	24
28	8½	13½	16	16	24	24
30	10	13½	16	18	24	24

* Full lengths may be obtained with these focal lengths, but the standpoint is so near to the sitter that good perspective cannot be expected.

Exposure Guide for Ciné-Kodak, Model BB, with f.1.9 Lens (Black and White Pictures Only)

(These figures, except as noted, apply only when the camera is operated at full, or normal speed.)

SUBJECT	TIME	Bright—No Clouds Over Sun	Light Clouds Over Sun	Cloudy Dull
		Diaphragm	Diaphragm	Diaphragm
A. Sea, Sky, Beach and Snow Scenes Distant Landscapes, Mountains	Apr.-Sept.	f.16	f.11	f.8
	Oct.-March	f.11	f.8	f.5.6
B. Close-ups* of Group A Open Landscapes, Games, etc., with no heavy shade	Apr.-Sept.	f.11	f.8	f.5.6
	Oct.-March	f.8	f.5.6	f.4
C. Close-ups* of Group B Street Scenes. Groups where houses or trees obstruct part of the light from the sky	Apr.-Sept.	f.8	f.5.6	f.4
	Oct.-March	f.5.6	f.4	f.2.8
D. Close-ups* of Group C Scenes on shady side of streets Boating scenes out of direct sunlight	Apr.-Sept.	f.5.6	f.4	f.2.8
	Oct.-March	f.4	f.2.8	f.1.9
E. Close-ups* of Group D Scenes on heavily shaded streets Scenes on heavily shaded porches	Apr.-Sept.	f.4	f.2.8	f.1.9
	Oct.-March	f.2.8	f.1.9	f.1.9 half-speed

*The term "close-up" means pictures taken from 2 feet to 6 feet from the lens. Figures above are for the hours from two hours after sunrise until two hours before sunset. To make pictures earlier or later, use the next larger diaphragm opening. The above figures apply to the temperate zone; for exposures in the tropics, see the manual.

These rules do not apply to Kodacolor—home movies in full color. Kodacolor pictures must be made with the diaphragm set at f.1.9, and the Kodacolor Filter in position before the lens (see folder).

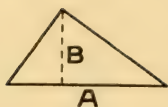
The above table can be used with the f.4.5 Long Focus Lens by substituting "f.4.5" wherever "f.4" appears, and "Too dark" wherever "f.2.8" or "f.1.9" appears. For "close-ups," subjects must not be nearer than 6 feet from the f.4.5 Long Focus Lens.

Use the half speed, see page 11, with the largest diaphragm opening in position, when the light conditions are unfavorable for making exposures at normal speed, as on very dark and rainy days; also for exposures earlier and later than the hours given above, when an opening larger than the largest one of the lens would be required.

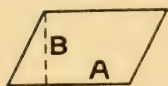
*The Projected Field for FILMO Camera Lenses, showing
Approximate Picture Areas Obtained*

Lenses Focal Length	Distance From Camera (Feet)																			
	Plane	Angle	1	1½	2	3	4	5	6	7	8	15	25	30	40	50	60	75	100	150
20 m/m	Horizontal	26° 4'	49	73	98	15	20	24	29	34	39	73	122	147	195	244	293	367	466	795
	Vertical	19° 54'	36	54	72	11	14	18	22	25	29	54	9	10	14	15	18	21	27	136
25 m/m	Horizontal	21° 22'	39	59	78	12	16	20	23	27	31	59	97	117	155	195	235	293	359	158
	Vertical	16° 9'	29	43	58	87	121	14	17	20	23	43	72	87	116	145	174	21	28	943
35 m/m	Horizontal	15° 37'	28	42	56	84	111	14	17	19	22	42	69	84	112	139	166	209	279	941
	Vertical	11° 41'	21	31	41	62	83	10	12	14	16	31	51	62	83	103	124	155	207	731
50 m/m	Horizontal	11° 4'	19	29	39	59	78	98	12	14	16	29	48	59	78	98	118	148	195	239
	Vertical	8° 14'	14	22	29	43	58	72	87	10	11	22	36	43	58	72	87	108	145	217
3"	Horizontal	7° 20'	13	19	26	38	51	64	77	90	10	19	32	38	51	64	77	96	128	225
	Vertical	5° 26'	09	14	19	28	38	47	57	66	76	14	24	28	38	47	57	71	95	142
3½"	Horizontal	5° 52'	10	15	21	31	41	51	62	72	82	15	26	31	41	51	62	77	103	155
	Vertical	4° 21'	07	11	15	23	30	38	46	51	61	11	19	23	30	38	46	57	76	114
4"	Horizontal	5° 30'	10	14	19	29	38	48	58	67	77	14	24	29	38	48	58	72	96	144
	Vertical	4° 5'	07	11	14	21	28	36	43	50	57	11	18	21	28	35	43	53	71	110
6"	Horizontal	3° 40'	06	09	13	19	26	32	38	45	51	96	16	19	23	32	38	48	64	96
	Vertical	2° 43'	05	07	09	14	19	24	28	33	38	71	12	14	19	24	28	35	47	71

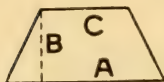
Mensuration



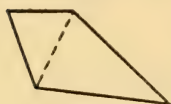
Area of triangle = base $\times \frac{1}{2}$ altitude
 $= A \times \frac{1}{2} B$



Area parallelogram = base $\times$ altitude
 $= A \times B$



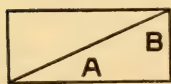
Area of trapezoid = $\frac{1}{2}$ (sum of parallel sides) $\times$ altitude
 $= \frac{1}{2} (A + C) \times B$



Area of trapezium = Divide into triangles and find area of each separately



Diagonal of a square = the square root of twice the square of one side
 $= 1.414 A$



Diagonal of a rectangle = the square root of the sum of the squares of the adjacent sides
 $= \sqrt{A^2 + B^2}$



Circumference of a circle
 $= \text{Diameter} \times 3.1416$
 $= 2 \times \text{radius} \times 3.1416$

Area of a circle
 $= \text{The square of the radius} \times 3.1416$
 $= \text{the square of the diameter} \times .7854$



A regular polygon, one whose sides and angles are all equal, area = $\frac{1}{2}$ sum of the sides $\times$ perpendicular from the center to one of the sides

The surface of a sphere = $4 \times \text{radius squared} \times 3.1416$

Contents of a sphere = $\frac{4}{3} \times \text{radius cubed} \times 3.1416$



Surface of a cylinder = area of both ends + length $\times$ circumference
 Contents of a cylinder = area of one end $\times$ length



Surface of a cone = area of base + circumference of base $\times \frac{1}{2}$ the slant height
 Contents of a cone = area of base $\times \frac{1}{3}$ altitude

To square a number multiply it by itself. To cube a number multiply it by itself and multiply the result by the number.

Useful Information

TROY WEIGHT

24 grains = 1 pennyweight (dwt.) 12 ounces = 1 pound
 20 dwts. = 1 ounce

Used for weighing gold, silver and jewels

APOTHECARIES' WEIGHT

20 grains = 1 scruple 8 drams = 1 ounce
 3 scruples = 1 dram 12 ounces = 1 pound
 The ounce and pound in this are the same as in Troy weight

AVOIRDUPOIS WEIGHT

27 $\frac{11}{32}$ grains = 1 dram 4 quarters = 1 cwt.
 16 drams = 1 ounce 2,000 lbs. = 1 short ton
 16 ounces = 1 pound 2,240 lbs. = 1 long ton
 25 pounds = 1 quarter

DRY MEASURE

2 pints = 1 quart 4 pecks = 1 bushel
 8 quarts = 1 peck 36 bushels = 1 chaldron

LIQUID MEASURE

4 gills = 1 pint 31 $\frac{1}{2}$ gallons = barrel
 2 pints = 1 quart 2 barrels = hogshead
 4 quarts = 1 gallon 16 fluid ounces = 1 pint

TIME MEASURE

60 seconds = 1 minute 24 hours = 1 day
 60 minutes = 1 hour 7 days = 1 week
 28, 29, 30 or 31 days = 1 calendar month (30 days = 1 month in computing interest)
 365 days = 1 year 366 days = 1 leap year

LONG MEASURE

12 inches = 1 foot 40 rods = 1 furlong
 3 feet = 1 yard 8 furlongs = 1 sta. mile
 5 $\frac{1}{2}$ yards = 1 rod 3 miles = 1 league
 5280 ft. = 1 mile

CLOTH MEASURE

2 $\frac{1}{4}$ inches = 1 nail 4 quarters = 1 yard
 4 nails = 1 quarter

SQUARE MEASURE

144 sq. inches = 1 sq. ft.	40 sq. rods = 1 rood
9 sq. ft. = 1 sq. yard	4 roods = 1 acre
30 $\frac{1}{4}$ sq. yards = 1 sq. rod	640 acres = 1 sq. mile
43560 sq. ft. = 1 acre	

SURVEYORS' MEASURE

7.92 inches = 1 link	4 rods = 1 chain
25 links = 1 rod	
10 sq. chains or 160 sq. rods = 1 acre	
640 acres = 1 sq. mile	
36 sq. miles (6 miles square) = 1 township	

CUBIC MEASURE

1,728 cubic in. = 1 cu. ft.	128 cu. ft. = 1 cord (wood)
27 cubic ft. = 1 cubic yard	40 cu. ft. = 1 ton (shpg.)
2,150.42 cubic inches = 1 standard bushel	
231 cubic inches = 1 standard gallon (liquid)	
1 cubic foot = $\frac{4}{5}$ of a bushel	

To find diameter of a circle multiply circumference by .31831.

To find circumference of a circle multiply diameter by 3.1416.

To find area of a circle multiply square of diameter by .7854.

To find surface of a ball multiply square of diameter by 3.1416.

To find side of an equal square multiply diameter by .8862.

To find cubic inches in a ball multiply cube of diameter by .5236.

A gallon of water (U S Standard) weighs 8 $\frac{1}{2}$ lbs. and contains 231 cubic inches.

A cubic foot of water contains 7 $\frac{1}{2}$ gallons, 1728 cubic inches, and weighs 62 $\frac{1}{2}$ lbs.



INTRINSIC BRIGHTNESS OF LIGHT SOURCES

<i>Light Source</i>	<i>Candle Power per Sq. M/M</i>
High Intensity White Flame Carbon Arc, Forced	1200
Pure Carbon Arc at 22 atmospheres (<i>about</i>)	1000
Sun at Zenith	920
High Intensity White Flame Carbon Arc, as usually operated	690
Positive Crater of Tantalum Arc (<i>about</i>)	500
Positive Crater of Solid Carbon Arc, on D.C.	180
Positive Crater of Cored Carbon Arc, on D.C.	130
Yellow Arc Stream	8.0
Magnetite Arc Stream	6.2
Mercury Vapor Tube	0.023
Moore Carbon Dioxide Tube	0.009

Electrical Energy

The power that is transmitted by any electric circuit depends on the current and the voltage. The unit, the watt, is the amount of power obtained from one ampere at one volt. This unit is too small for ordinary purposes and the kilowatt equal to 1000 watts is used.

For D. C. circuits:

$$W = I \times E$$

W = Power in watts

I = Current in amperes

E = Electromotive force in volts

In A. C. circuits the entire current is not always available for doing work. This calls for another term in the energy equation, the power factor, which is the ratio of the current available for power to the total current. For single-phase A. C. circuits the equation becomes

$$W = I \times E \times P$$

P = Power factor of the circuit

For two-phase A.C.

$$W = 2 \times I \times E \times P$$

For three-phase A.C.

$$W = 1.73 \times I \times E \times P$$

ELECTRICAL AND MECHANICAL
CONVERSION FACTORS

$$1 \text{ H.P.} = 746 \text{ watts} = .746 \text{ kw.}$$

$$1 \text{ kw.} = 1.344 \text{ H.P.} = \text{approx. } 1\frac{1}{3} \text{ H.P.}$$

Electricity

OHMIC RESISTANCE

The resistance of a uniform electric conductor at 0°, Centigrade, is given by the formula:

$$R \text{ (in ohms)} = \rho L/A$$

L = length of conductor in inches

A = Cross-section in square inches

ρ = Resistivity of conductor at 0° C., values of which are given in the following table

TABLE OF RESISTIVITIES

(Resistivity is the resistance in ohms between any two opposite faces of a 1 inch cube of the material. It is given in microhms or millionths of an ohm.)*

<i>Metal</i>	<i>Resistivity at 0° C. (in microhms)</i>
Aluminum (annealed)	1.14
Aluminum (commercial)	1.05
Aluminum bronze	4.96
Bismuth (compressed)	51.2
Brass	2.82
Copper (drawn)	0.637
Copper (annealed)	0.625
German silver	8.23
Gold (annealed)	0.803
Iron (wrought)	3.82
Lead (compressed)	7.68
Magnesium	1.72
Mercury	37.1
Nickel (annealed)	4.89
Platinum (annealed)	3.53
Silver (annealed)	0.575
Tin	5.16
Tungsten	2.
Zinc (pressed)	2.28

* This definition applies to English units and to the numerical values given in the table. In general, resistivity is the resistance of a unit cube. The resistance of a conductor at any temperature is

$$R_2 = R_1 \frac{(1 + at_2)}{(1 + at_1)}$$

in which

R_1 = known resistance at a temperature t_1 degrees Centigrade

R_2 = required resistance at a temperature t_2 degrees Centigrade

a = temperature coefficient of electrical resistance, the value of which is given for different metals in the following table.

Thermometer Scales

There are two thermometer scales in general use in this country at the present time, the Fahrenheit and the Centigrade. On the Fahrenheit scale the melting point of ice is 32° and the boiling point of water at sea-level is 212° . On the Centigrade scale 0° is the melting point of ice and 100° the boiling point of water. Another scale, the Absolute, is sometimes used. This takes its zero at a point assumed to be the lowest temperature that can exist. This point was calculated from the contraction of gases when cooled and found to be -273° C, i. e., 273° below zero Centigrade. The size of the degrees of the Centigrade and Absolute scales is the same, so to convert degrees Centigrade to Absolute all that is necessary is to add 273.

To convert degrees Centigrade to Fahrenheit multiply by 1.8 and add 32.

To convert degrees Fahrenheit to Centigrade, subtract 32 and divide the result by 1.8. Care should be taken that the sign of the result is correct when the temperature is below the freezing point of water.

(The constant 1.8 is obtained as follows: Between the freezing and boiling points of water there are 100° C and $212^{\circ}-32^{\circ}=180^{\circ}$ F. Therefore, 1° C = 1.8° F. The factor 32 arises from the fact that 0° C corresponds to 32° F.)

TEMPERATURE COEFFICIENTS OF ELECTRICAL
RESISTANCE

<i>Metal</i>	<i>Temperature Coefficient (approximately) for 1° C.</i>
Aluminium (commercial)	0.00435
Copper (annealed)	0.00400
German silver	0.00036
Gold (annealed)	0.00365
Iron (wrought)	0.00463
Mercury	0.00072
Platinum	0.00247
Silver	0.00377
Tungsten	0.00570
Zinc (pressed)	0.00365

Note. The temperature coefficient of a material is its increase in resistance for each degree Centigrade rise in temperature, and it is expressed as a decimal fraction of the resistance at 0° C.

Decimal Equivalents of Fractions and Equivalents of Fractions of an Inch in Mm.

$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$	mm.	Decim. of an inch	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$	mm.	Decim. of an inch
				1	.198	.0078125					65	12.898	.5078125
				2	.397	.0156250					66	13.097	.515625
				3	.595	.0234375					67	13.295	.5234375
			1	2	.794	.031250					68	13.494	.531250
				5	.992	.0390625					69	13.692	.5390625
			3	6	1.191	.046875					70	13.891	.546875
				7	1.389	.0546875					71	14.089	.5546875
			1	2	4	8	1.588	.062500			72	14.288	.562500
				9	1.786	.0703125					73	14.486	.5703125
				5	10	1.984	.078125				74	14.684	.578125
				11	2.183	.0859375					75	14.883	.5859375
			3	6	12	2.381	.093750				76	15.081	.593750
				13	2.580	.1015625					77	15.280	.6015625
				7	14	2.778	.109375				78	15.478	.609375
				15	2.977	.1171875					79	15.677	.6171875
			1	2	4	8	16	3.175	.125000		80	15.875	.625000
				17	3.373	.1328125					81	16.073	.6328125
				9	18	3.572	.140625				82	16.272	.640625
				19	3.770	.1484375					83	16.470	.6484375
			5	10	20	3.969	.156250				84	16.669	.656250
				21	4.167	.1640625					85	16.867	.6640625
				11	22	4.366	.171875				86	17.066	.671875
				23	4.564	.1796875					87	17.264	.6796875
			3	6	12	24	4.763	.187500			88	17.463	.687500
				25	4.961	.1953125					89	17.661	.6953125
				13	26	5.159	.203125				90	17.859	.703125
				27	5.358	.2109375					91	18.058	.7109375
				7	14	28	5.556	.218750			92	18.256	.718750
				29	5.755	.2265625					93	18.455	.7265625
				15	30	5.953	.234375				94	18.653	.734375
				31	6.152	.2421875					95	18.852	.7421875
			2	4	8	16	32	6.350	.250000		96	19.050	.750000
				33	6.548	.2578125					97	19.248	.7578125
				17	34	6.747	.265625				98	19.447	.765625
				35	6.945	.2734375					99	19.645	.7734375
				9	18	36	7.144	.281250			100	19.844	.78125
				37	7.342	.2890625					101	20.042	.7890625
				19	38	7.541	.296875				102	20.241	.796875
				39	7.739	.3046875					103	20.439	.8046875
			5	10	20	40	7.938	.312500			104	20.638	.8125
				41	8.136	.3203125					105	20.836	.8203125
				21	42	8.334	.328125				106	21.034	.828125
				43	8.533	.3359375					107	21.233	.8359375
				11	22	44	8.731	.343750			108	21.431	.84375
				45	8.930	.3515625					109	21.630	.8515625
				23	46	9.128	.359375				110	21.828	.859375
				47	9.327	.3671875					111	22.027	.8671875
			3	6	12	24	48	9.525	.375000		112	22.225	.875000
				49	9.723	.3828125					113	22.423	.8828125
				25	50	9.922	.390625				114	22.622	.890625
				51	10.120	.3984375					115	22.820	.8984375
				13	26	52	10.319	.406250			116	23.019	.906250
				53	10.517	.4140625					117	23.217	.9140625
				27	54	10.716	.421875				118	23.416	.921875
				55	10.914	.4296875					119	23.614	.9296875
				7	14	28	56	11.113	.437500		120	23.813	.937500
				57	11.311	.4453125					121	24.011	.9453125
				29	58	11.509	.453125				122	24.209	.953125
				59	11.708	.4609375					123	24.408	.9609375
				15	30	60	11.906	.46875			124	24.606	.96875
				61	12.105	.4765625					125	24.805	.9765625
				31	62	12.303	.484375				126	25.003	.984375
				63	12.502	.4921875					127	25.202	.9921875
			4	8	16	32	64	12.700	.500000		128	25.400	1.0000000

NATIONAL HIGH INTENSITY PROJECTOR COMBINATIONS

GENERAL ELECTRIC LAMPS

<i>Arc Amper- age</i>		<i>Size</i>	<i>Kind</i>
50	Positive	9m/m x 20"	Nat'l H. I. White Flame Projector
	Negative	11/32 x 9"	Nat'l Orotip Cored Projector
75	Positive	11m/m x 20"	Nat'l H. I. White Flame Projector
	Negative	3/8 x 9"	Nat'l Orotip Cored Projector
100-120	Positive	13.6m/m x 20"	Nat'l H. I. White Flame Projector
	Negative	7/16 x 9"	Nat'l Orotip Cored Projector

The trims given on this page are suggested by the National Carbon Company as giving best results in the projection of motion pictures.

H & C AND SUNLIGHT ARC (SPERRY) LAMPS

<i>Arc Amper- age</i>		<i>Size</i>	<i>Kind</i>
50	Positive	9m/m x 20"	Nat'l H. I. White Flame Projector
	Negative	5/16 x 9"	Nat'l Orotip Cored Projector
75	Positive	11m/m x 20"	Nat'l H. I. White Flame Projector
	Negative	11/32 x 9"	Nat'l Orotip Cored Projector
100-120	Positive	13.6m/m x 20"	Nat'l H. I. White Flame Projector
	Negative	3/8 x 9"	Nat'l Orotip Cored Projector

ASHCRAFT LAMPS

<i>Arc Amper- age</i>		<i>Size</i>	<i>Kind</i>
80	Positive	1/2 x 12"	Nat'l White Flame Cored
	Negative	3/8 x 9"	Nat'l Orotip Cored Projector
100 to 120	Positive	13.6m/m x 20"	Nat'l H. I. White Flame Projector
	Negative	3/8 x 9"	Nat'l Orotip Cored Projector

Carrying Capacity of Copper Wires

The following table, showing the allowable carrying capacity of copper wires and cables of 98% conductivity, according to the standard adopted by the American Institute of Electrical Engineers, must be followed in placing interior conductors.

For insulated aluminum wire the safe carrying capacity is 84% of that given in the following tables for copper wire with the same kind of insulation.

<i>B. & S. Gauge</i>	<i>Circular Mils</i>	<i>Table A Rubber Insulation Amperes</i>	<i>Table B Other Insulations Amperes</i>
18	1,624	3	5
16	2,583	6	8
14	4,107	12	16
12	6,530	17	23
10	10,380	24	32
8	16,510	33	46
6	26,250	46	65
5	33,100	54	77
4	41,740	65	92
3	52,630	76	110
2	66,370	90	131
1	83,690	107	156
0	105,500	127	185
00	133,100	150	220
000	167,800	177	262
0000	211,600	210	312
	Circular Mils.		
	200,000	200	300
	300,000	270	400
	400,000	330	500
	500,000	390	590
	600,000	450	680
	700,000	500	760
	800,000	550	840
	900,000	600	920
	1,000,000	650	1,000
	1,100,000	690	1,080
	1,200,000	730	1,150
	1,300,000	770	1,220
	1,400,000	810	1,290
	1,500,000	850	1,360
	1,600,000	890	1,430
	1,700,000	930	1,490
	1,800,000	970	1,550
	1,900,000	1,010	1,610
	2,000,000	1,050	1,670

The lower limit is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the above tables.

Properties of Copper Wire

ENGLISH SYSTEM—BROWN & SHARPE GAUGE

<i>Numbers</i>	<i>Diameters in mils.</i>	<i>Areas in Circular mils. C.M. = d^2</i>	<i>Weights 1000 ft. Pounds</i>	<i>Resistance per 1000 ft. in Interna- tional Ohms At 75° F</i>
0000	460.	211 600.	641.	.049 66
000	410.	168 100.	509.	.062 51
00	365.	133 225.	403.	.078 87
0	325.	105 625.	320.	.099 48
1	289.	83 521.	253.	.125 8
2	258.	66 564.	202.	.157 9
3	229.	52 441.	159.	.200 4
4	204.	41 616.	126.	.252 5
5	182.	33 124.	100.	.317 2
6	162.	26 244.	79.	.400 4
7	144.	20 736.	63.	.506 7
8	128.	16 384.	50.	.641 3
9	114.	12 996.	39.	.808 5
10	102.	10 404.	32.	1.01
11	91.	8 281.	25.	1.269
12	81.	6 561.	20.	1.601
13	72.	5 184.	15.7	2.027
14	64.	4 096.	12.4	2.565
15	57.	3 249.	9.8	3.234
16	51.	2 601.	7.9	4.04
17	45.	2 025.	6.1	5.189
18	40.	1 600.	4.8	6.567
19	36.	1 296.	3.9	8.108
20	32.	1 024.	3.1	10.26
21	28.5	812.3	2.5	12.94
22	25.3	640.1	1.9	16.41
23	22.6	510.8	1.5	20.57
24	20.1	404.	1.2	26.01
25	17.9	320.4	.97	32.79
26	15.9	252.8	.77	41.56
27	14.2	201.6	.61	52.11
28	12.6	158.8	.48	66.18
29	11.3	127.7	.39	82.29
30	10.	100.	.3	105.1
31	8.9	79.2	.24	132.7
32	8.	64.	.19	164.2
33	7.1	50.4	.15	208.4
34	6.3	39.7	.12	264.7
35	5.6	31.4	.095	335.1
36	5.	25.	.076	420.3

METRIC EQUIVALENTS

Length

Cm. = .3937 In.	In. = 2.54 Cm.
Meter = 3.28 Ft.	Ft. = .305 Meter
Meter = 1.09 Yd.	Yd. = .914 Meter
Kilom. = .621 Mile	Mile = 1.61 Kilom.

Area

Sq. Cm. = 0.1550 Sq. In.	Sq. In. = 6.452 Sq. Cm.
Sq. M. = 10.764 Sq. F.	Sq. Ft. = .0929 Sq. M.
Sq. M. = 1.196 Sq. Yd.	Sq. Yd. = .836 Sq. M.
Hectare = 2.47 Acres	Acre = 0.405 Hectare
Sq. Kilom. = .386 Sq. mi.	Sq. mi. = 2.59 Sq. Kilom.

Volume

Cu. Cm. = 0.353 Cu. ft.	Cu. In. = 16.4 Cu. Cm.
Cu. M. = 35.31 Cu. ft.	Cu. Ft. = .028 Cu. M.
Cu. M. = 1.308 Cu. Yd.	Cu. Yd. = .765 Cu. M.

Capacity

Litre = .0353 Cu. Ft.	Cu. Ft. = 28.32 Litres
Litre = .2642 Gal. (U. S.)	Gal. = 3.785 Litres
Litre = 61.023 Cu. In.	Cu. In. = .0164 Litre

Weight

Gram = 15.423 Grains	Grain = .0694 Gram
Gram = .0353 Ounce	Ounce = 28.34 Gram
Kilogram = 2.205 Lb.	Pound = .454 Kilogram
Kilogram = .0011 Ton	Ton = 907.03 Kilogram
Tonne = 1.1025 Ton	Ton = .907 Tonne
Grams per cubic meter = .437 grains per cu. ft.	
Grains per cubic foot = 2.288 grams per cubic meter.	
Kilograms per cubic meter = .0624 pounds per cubic foot.	
Pounds per cubic foot = 16.02 Kilograms per cu. meter	

Pressure

Kilograms per square Cm. = 14.225 pounds per square inch.	
Pounds per square inch = .0703 Kilograms per square Cm.	
Kilograms per sq. meter = .205 pounds per sq. foot.	
Pounds per sq. ft. = 4.88 Kilograms per sq. meter.	
Kilograms per sq. Cm. = .968 atmosphere.	
Atmosphere = 1.033 Kilograms per sq. Cm.	

Hydraulic Formulas

Lb. per sq. in. = $0.434 \times$ head of water in ft.
Head in feet = $2.3 \times$ pounds per sq. in.
Weight per cu. ft. of water = 62.4 pounds.
Weight per gal. of water = 8.33 pounds.
Gallons per cu. ft. = 7.48

Miscellaneous

Kilogrammeter = 7.233 foot-pounds
Foot-pounds = .1384 kilogrammeter
Cheval (French horse power) = .986 h. p.
Horse-power = 1.014 cheval
Litre per second = 2.12 cu. ft. per minute
Litre per second = 15.85 U. S. Gallons per minute

Definitions

Dyne = Unit for force
Erg = Unit of work
Watt = Unit of power = Volt ampere
Dyne is the force which acting on a mass of one gram driving on second will give it a velocity of one Cm. per second.
1 Erg = 1 Dyne—Cm. = .00000007373 ft. lb.
1 Watt = 10 million ergs per second.
1 Watt = 7373 foot-pounds per second.
1 Watt = .00134 H. P.

Equivalents of Electrical Units

1 Kilowatt = 1000 watts
1 Kilowatt = 1.34 H.P.
1 Kilowatt = 44.257 foot-pounds per minute
1 Kilowatt = 56.87 B.T.U. per minute
1 horse-power = 746 Watts
1 horse-power = 33,000 ft.-lbs. per minute
1 horse-power = 42.41 B. T. U. per minute
1 B. T. U. (British Thermal Unit) = 778 foot-pounds
1 B. T. U. = 0.2930 watt-hour
1 joule = 1 watt-second

MACHINERY DEVELOPMENTS IN THE MOTION PICTURE INDUSTRY

*Hal Hall**

TO record and describe in detail all the mechanical improvements in the various phases of the motion picture industry during the past year would require a volume in itself almost as large as this Annual. So, no attempt will be made here to give a record of every forward step or invention. The writer will merely touch the high spots and briefly touch upon those new devices and improvements which have been of the greatest importance, and which are the most outstanding.

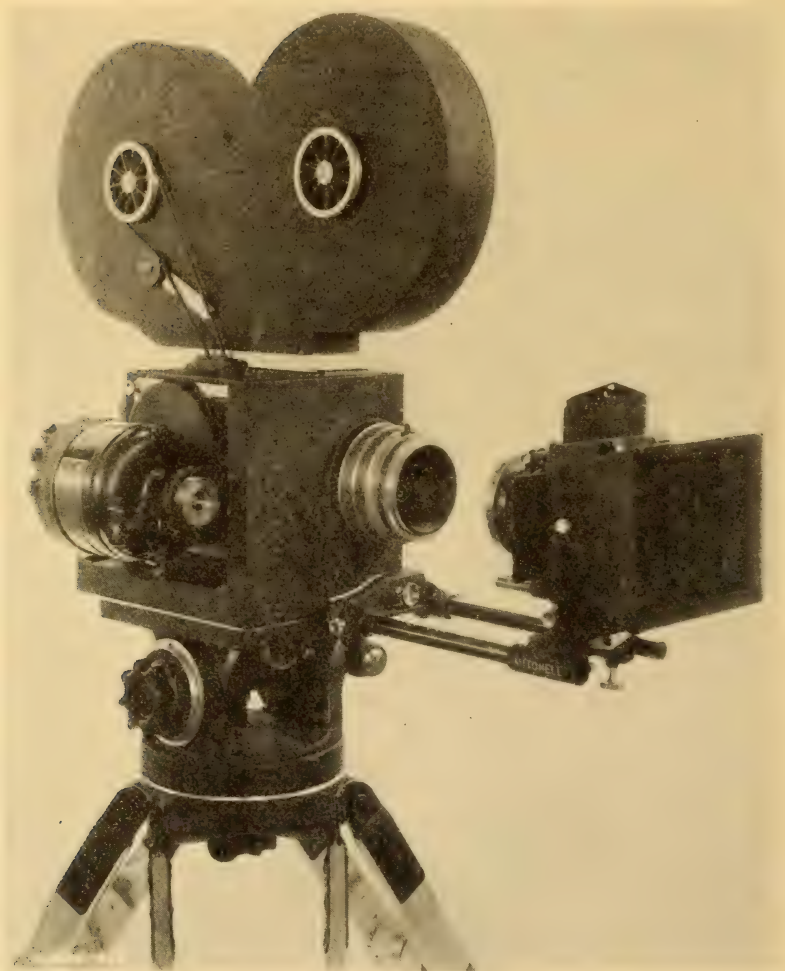
Perhaps, to the motion picture photographer, the most important development mechanically during the past year was the development of the new Mitchell silent camera. This camera, retaining the same general form and arrangement of its essential units, and designed by George Mitchell, is really quiet. Not perfectly noiseless to the ear of the exacting recordist, perhaps, but to date, the most silent camera to be introduced, and the nearest thing to perfect silence that has appeared since sound made its appearance in the motion picture industry.

The silence in the new camera is secured through two chief factors. First, simplification of the mechanism. Second, insulation of the camera box so that what noise there is does not leave the camera. The movement is simplified to an almost unbelievable degree. Only two pairs of gears in the entire camera; one to draw the intermittent movement from the main shaft; the other drives the shutter shaft. The movement is actuated by eccentrics rather than gears and cams. The dissolving shutter has been eliminated. The angular aperture of the shutter is adjustable from the rear when the camera is not in operation, and is fitted with a positive lock. Two types of shutter are offered; one in which the opening may be varied from 175 degrees to 0 degrees; one in which the minimum opening is but 30 degrees, the maximum 210 degrees.

The camera case is insulated with a layer of cork, placed between the inner and outer walls. The magazines are likewise insulated. The camera and magazine are insulated from each other, there being no metallic contact between the two. Insulation of the tripod head also did its bit toward making for silence. Special synchronous motors have also been insulated so that the Mitchell company can be proud of its job.

Much has been heard of another new camera that is being prepared by the Bell & Howell Company. Predictions are that this camera will be absolutely silent when the company introduces it to the profession. Work on this camera has been progressing for more than a year, but officials of the Bell & Howell Company will not present it until they are satisfied that it is absolutely noiseless.

*Editor, American Cinematographer; Editor, Cinematographic Annual.

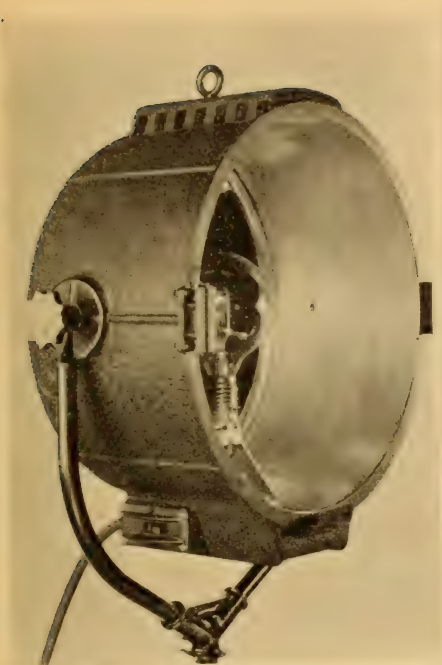


The Mitchell Silent Camera

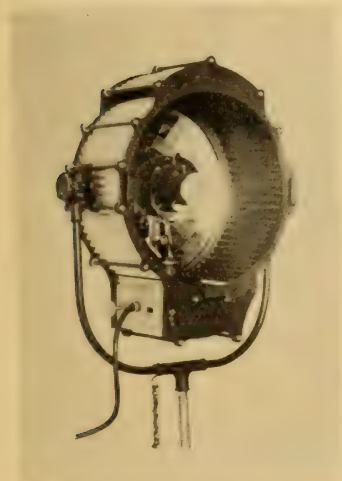
The Radio Corporation of America has announced the perfection of a silent 48 cycle camera motor which eliminates the necessity of gears between the motor and camera. This firm has also announced a 720 r.p.m. silent camera motor for use on the Bell & Howell and the Fearless cameras.

Another camera has been designed by Huguenard and Magnan, employing four lenses and taking twelve pictures in an area the size of a standard 25 mm. frame. With a linear velocity of the film equal to 3 meters per second, 2400 pictures may be exposed per second.

In the field of studio illumination, the most outstanding development in the past year has been the production of silicon aluminum housings, designed particularly to eliminate the objectionable noises commonly given off by the older sheet-iron housings when a lamp is warming up. Both Mole-Richardson, Inc., and the Lakin Company adopted the aluminum housings.

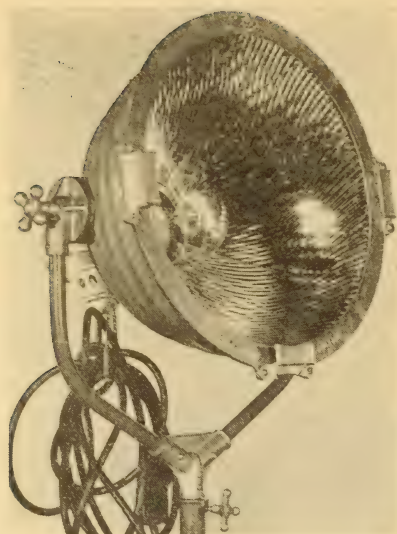


Two Mole-Richardson lamps with silicon aluminum housing.

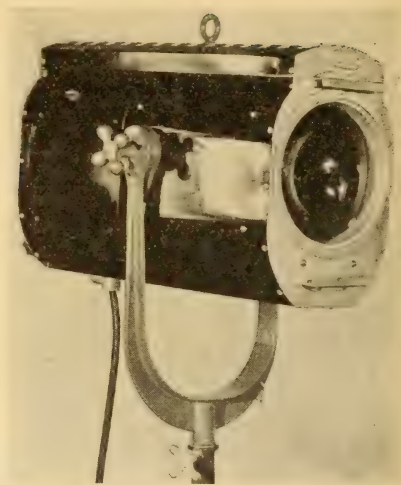


Two new lamps from the Stone Fog Light Corporation. Right, the adjustable lamp for closeups.





A Laco Rifle

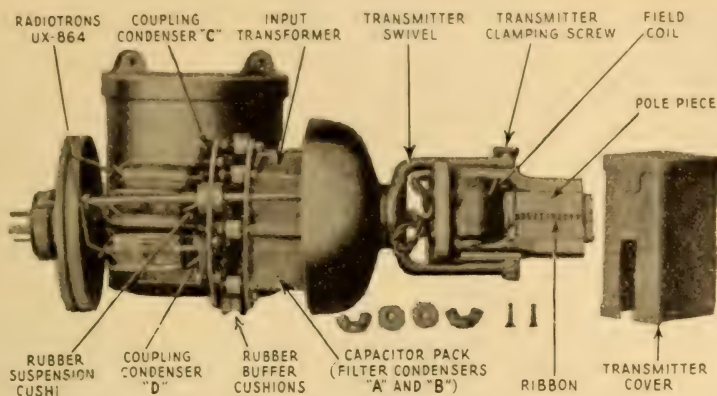


A Laco Burre! Spot

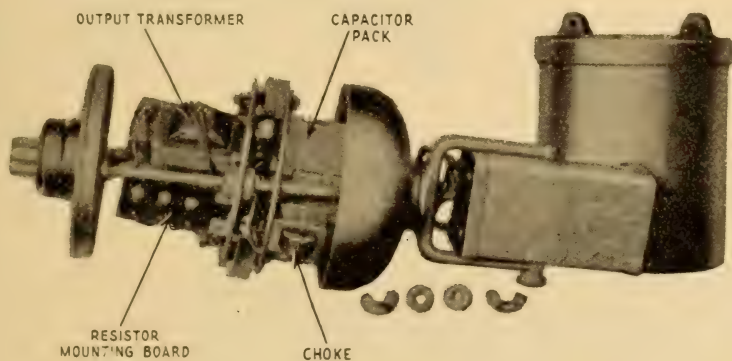
Mole-Richardson also introduced a new lamp for use especially in making closeups. This lamp is adjustable to all angles, and can be adjusted from 10 feet to the floor. It uses a 1000 Watt T20 bulb. A very similar lamp was also introduced by the Stone Fog Light Corporation. This lamp is adaptable from 250 Watts to 1000 Watts and weighs 27 pounds. Both lamps fill a definite studio need. The Stone Fog Light Corporation also introduced a new 18 inch studio lamp weighing but 36 pounds. Focal adjustment is made by means of a worm and gear arrangement. A new "spill ring" was also introduced by the Stone Fog Light concern.

In the sound recording field the outstanding achievement in the mechanical development was reduction of ground noise. Two methods were developed; a biased valve method by Western Electric, and the RCA method which consists of rectifying a portion of the output of the recording amplifier, and using this current to keep the amount of light admitted to the film at a minimum.

In the microphone field, RCA developed a new microphone for which directional pickup characteristics are claimed. It is called the Ribbon microphone. The ribbon microphone consists of two main assemblies, a microphone amplifier housed in a cylindrical aluminum case ten inches long and six inches in diameter, and the ribbon microphone transmitter suspended in a swivel mounting at the base of the amplifier housing. The swivel mount permits the aiming of the transmitter in any desired direction. The transmitter is enclosed within a perforated aluminum casing which protects it from mechanical injury. The illustrations show the microphone and the circuit wiring.

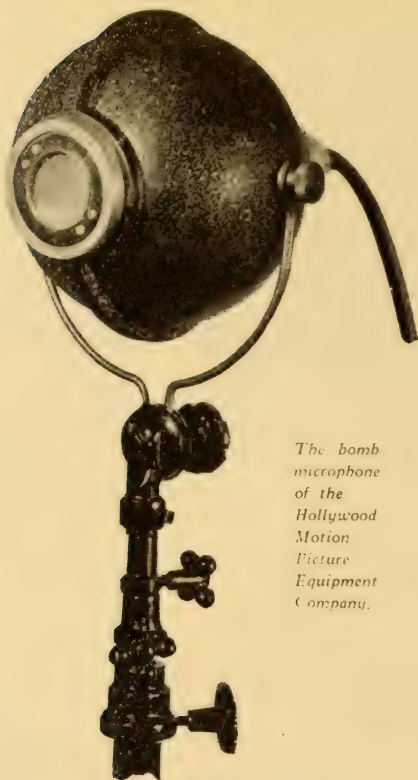


Type PB-17 Ribbon Microphone with covers removed to show radiotrons and arrangement of parts



Type PB-17 Ribbon Microphone with amplifier cover removed (reverse of Figure 2)

A new "bomb" type of microphone has also been developed by the sound department at the Metro-Goldwyn-Mayer studios. This is said to have proven very satisfactory. Another "bomb" microphone has also been introduced by the Hollywood Motion Picture Equipment Company.



*The bomb
microphone
of the
Hollywood
Motion
Picture
Equipment
Company.*

Several systems of portable sound-on-film recording equipment have gained considerable prominence during the past year. The Tanar portable recording unit, both single and double systems, was developed by the Tanar Corporation of Hollywood.

Audio-Camex was another portable system developed in Hollywood. And the most recent portable system has been introduced by the Hollywood Motion Picture Equipment Company. A picture of this equipment which is called the "Artreeves" Recording System, is found on page 416. Blue Seal Sound Devices also developed a portable recorder which is called the Cineglow Sound System. RCA is another organization that has brought out a portable.

A studio sound system known as the "Rico" Studio Recording System, and placed on the market by the Radio Installation Company of Los Angeles, made its appearance during the year at a price that is considered unusually low. This system is claimed to have been designed for use in tropical climates and is said to be absolutely moisture proof. Its makers state that it was designed primarily for the use of foreign producers who had to have equipment at a low figure.

Depue of Chicago has announced a 35 mm. combination sound and picture printer, as well as a printer for color picture work. Duplex

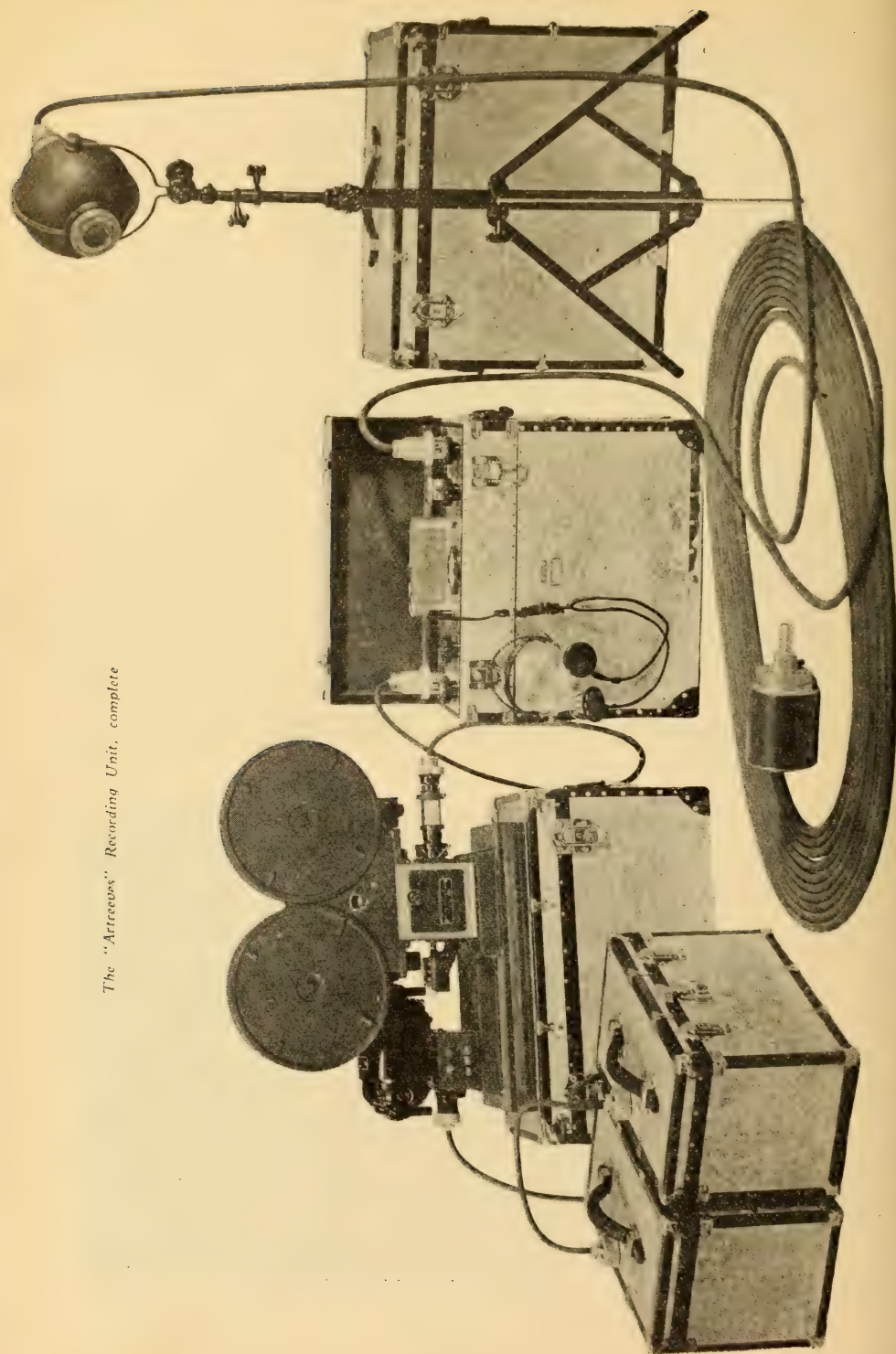


*The Tanar Single System
Portable Recording Unit,
complete*

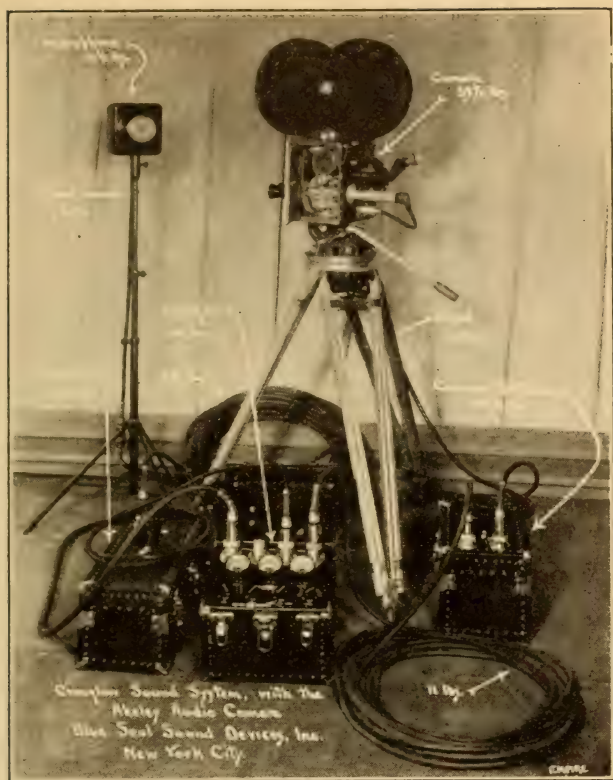


*The R-C-A Portable
Recorder in operation*

The "Artrecoos" Recording Unit, complete



*The
Cineglow
Portable
Sound
Recording
Unit*

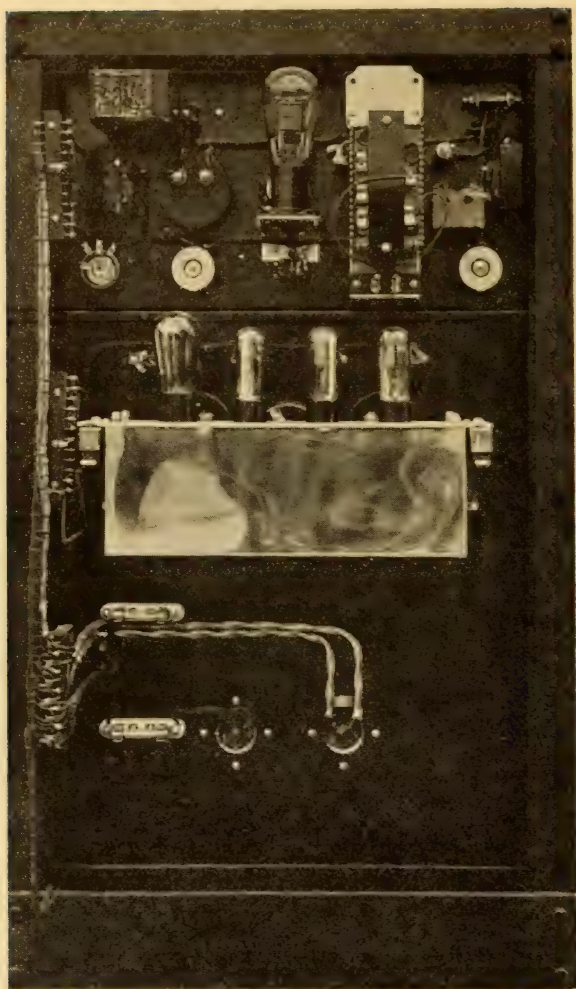


*Complete Sound System, with the
Rexley Audio Camera
Allen Seal Sound Service, Inc.
New York City*

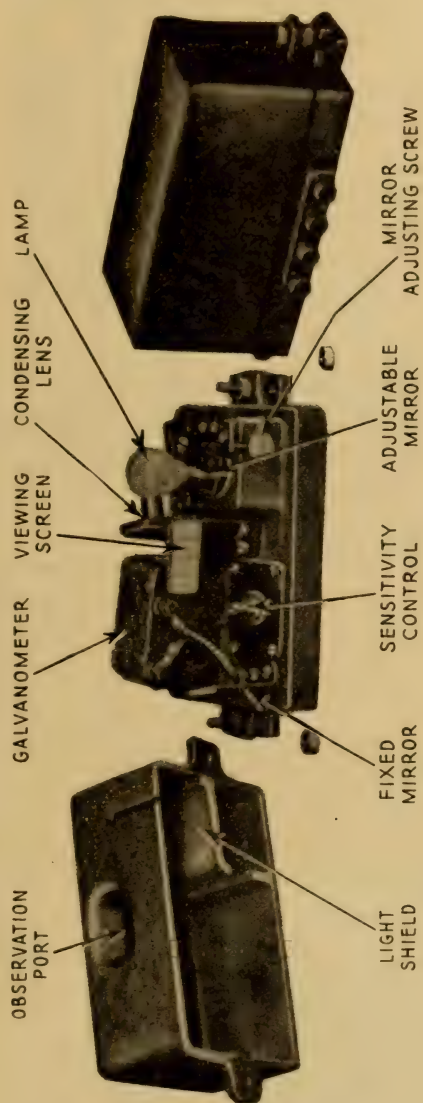
Motion Picture Industries of New York has also introduced a combined picture and sound printer, as well as equipment for handling bi-pack negatives. Bell & Howell has introduced a new, fully automatic continuous production printer for printing simultaneously both picture and sound. A photograph of this printer is shown on page 276 of this Annual.

RCA has also introduced a remote level indicator known as Type PB-30. This device is used in conjunction with a sound-on-film recorder, for the purpose of visually indicating at some point remote from the recorder, the volume level of sounds being recorded. It consists essentially of a small recording optical system mounted in a small case of rectangular shape. Basically, the unit operates as does any Photophone sound-on-film recorder except that the light beam is finally directed against a white screen for visual monitoring instead of being directed through an optical lens barrel assembly to a film.

Bell & Howell has presented a new model film splicer for 35 mm. film, but which is equipped with disappearing pilot pins for splicing 16 mm. film as well. It has a heating unit which maintains a constant temperature in all parts of the machine with which the film comes in contact.



Back view of Amplifier Rack of the "Rico" sound recording unit. The upper panel contains noise reduction amplifier. Center is high gain recording amplifier. Bottom is power and terminal panel.



The Type PB-30 Remote Level Indicator

Center - Front view with cover removed to show location of parts

Right - Cover of the unit shown in the center view

Left - Rear view showing location of terminals

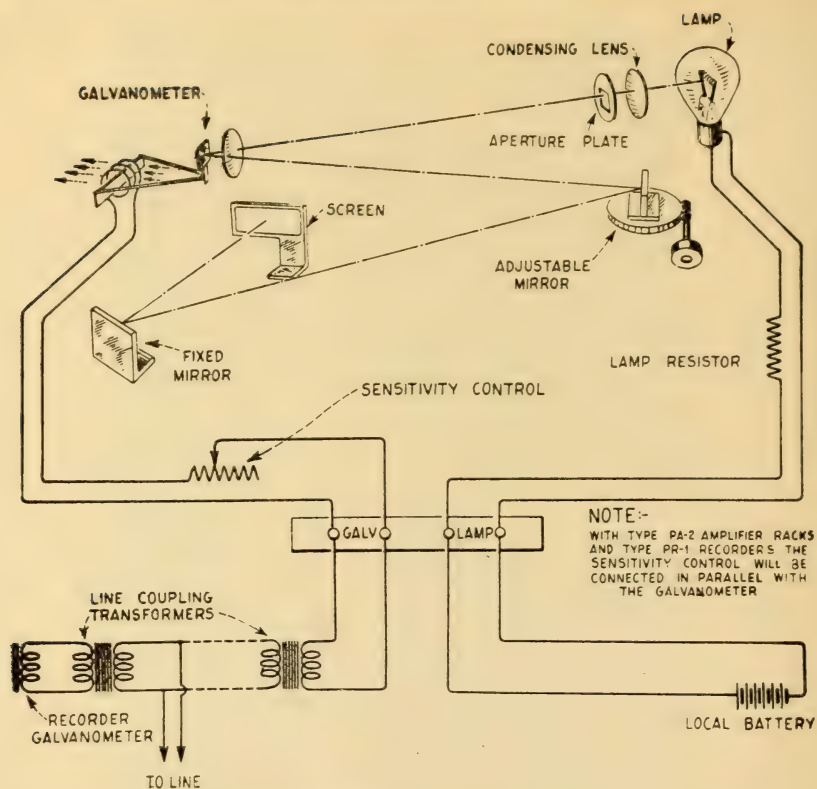
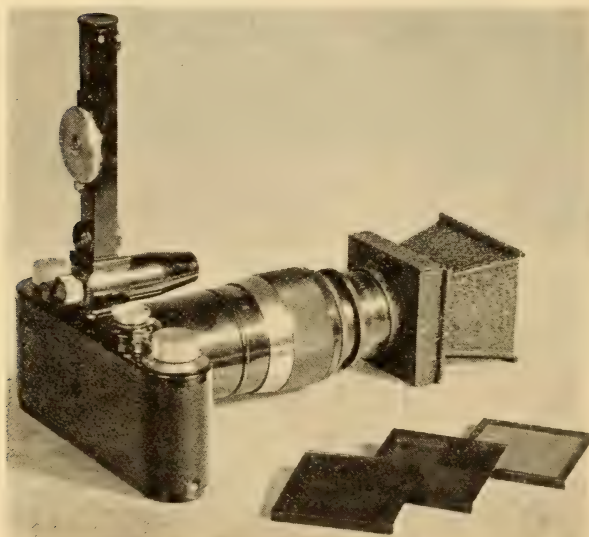


Diagram illustrating principle of operation and electrical connections of type PB-30 Remote Level Indicator



The Leica Camera with
the new sunshade
attached.



An example of the new Eastman Sound Patch.

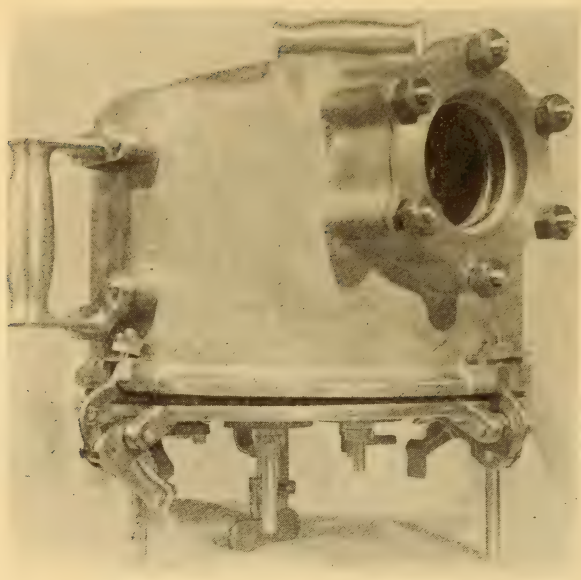
Eastman Kodak Company placed on the market a clever film patch for sound film patching. This patch is made of light-weight, opaque film. It is claimed that this patch is practically inaudible.

Western Electric announced an electrical reverberation meter for measuring reverberation time. This method is similar in principle to the Sabine method only an electro acoustical ear of controllable threshold sensibility is substituted for the human ear.

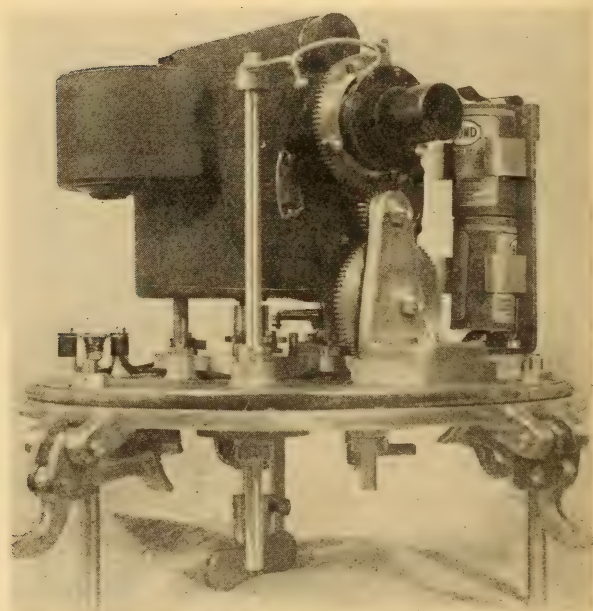
Among the Hollywood studios a new cine filter holder and a sunshade, added to the Leica camera, has made this equipment one that is much used. The new devices were designed by Jackson Rose, A. S. C., and makes easy the use of the many density and color filters which, in turn, makes it possible for the cameraman to use this camera for making lighting and composition tests.

Another important piece of equipment developed during the past year is a housing for an Eyemo camera devised for the purpose of under-water photography. This was developed by E.R.F. Johnson of Camden, N. J., for the use of Alfred L. Gilks, A.S.C. This device makes under-water cinematography comparatively easy. The photographs on the following page give an excellent idea of the construction of this housing device.

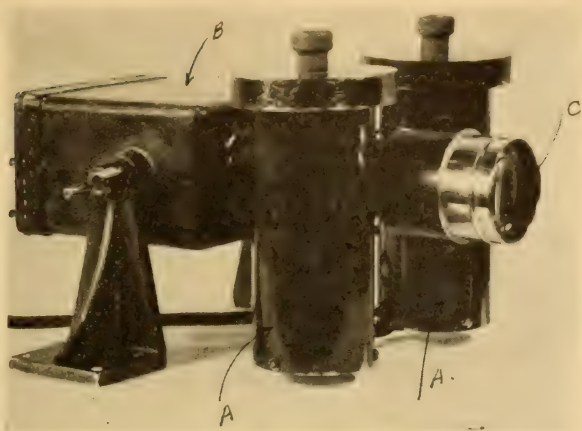
M. W. Palmer of the Paramount Studio, Long Island, N. Y., has developed a unique device for projecting footage numbers. It is shown in the two pictures accompanying this brief description. The device, according to Mr. Palmer, can be used in various ways in connection with sound pictures, as for instance: the introduction of sound effects in scenes already taken, the footage numbers appearing on the screen give an advance warning of the approach and finish of the scene in



*The underwater camera
housing designed for
an Eyemo*

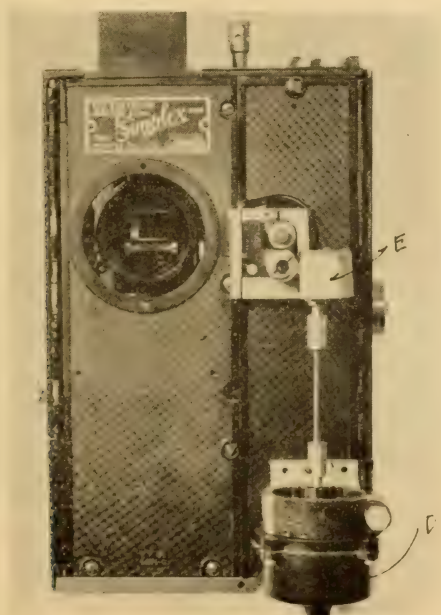


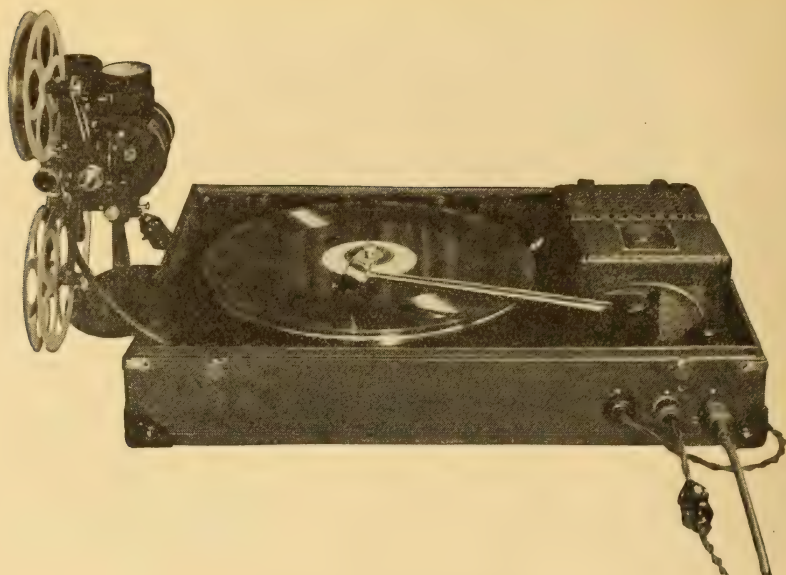
*Here is how the Eyemo
fits in the underwater
housing.*



question, so that the sound can be synchronized exactly. Another application is the translation of the film from one language to another, and it can also be used in connection with title music.

Box "B" contains an electrical operated Veeder counter. The face of this counter is illuminated by two 10 Watt lamps contained in the lamp houses "A." The image of the counter numbers is thrown on a small screen below the main screen by the lens "C." A contactor "D" attached to the projector is driven by a worm gear "E." This contactor makes one contact for every 16 frames, thereby moving the counter ahead one unit.

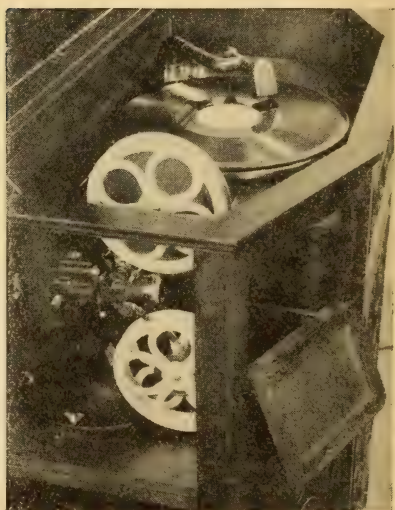




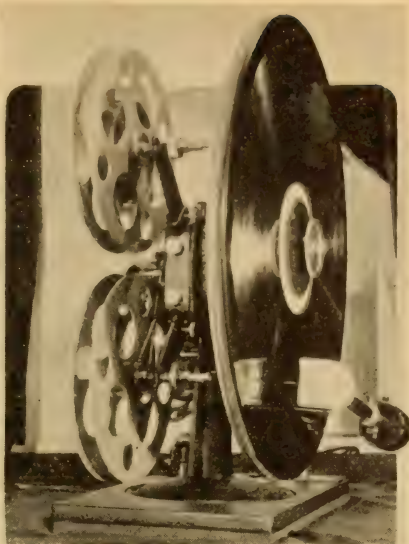
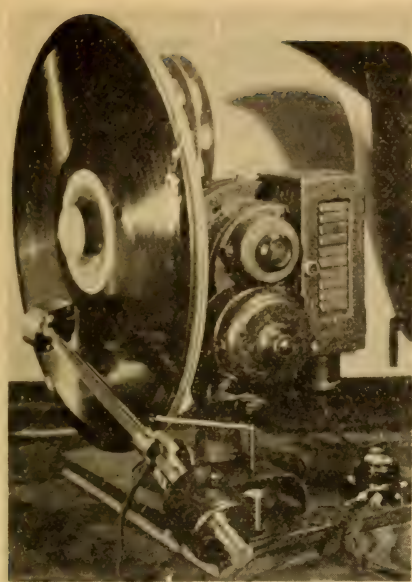
The Bell & Howell Filmophone



B. & H. microphone arrangement that enables operator to use his own voice as picture runs. And his remarks come through the loud speaker.



B. & H. combination set combining home talkies, home movies, radio and phonograph.



Two views of the Animatophone

The only alteration necessary to the projector is to bore four holes to attach the base of the contactor. A push button is provided in the operating room, so that the counter can be reset to zero at any time.

In the 16 millimeter field there has been a vast number of new devices placed upon the market during the last twelve months. Outstanding among them are the Filmophone, by Bell & Howell, and the Animatophone by the Victor Animatograph Corporation. These two home talking projectors have aroused tremendous enthusiasm in the field of home talkies.

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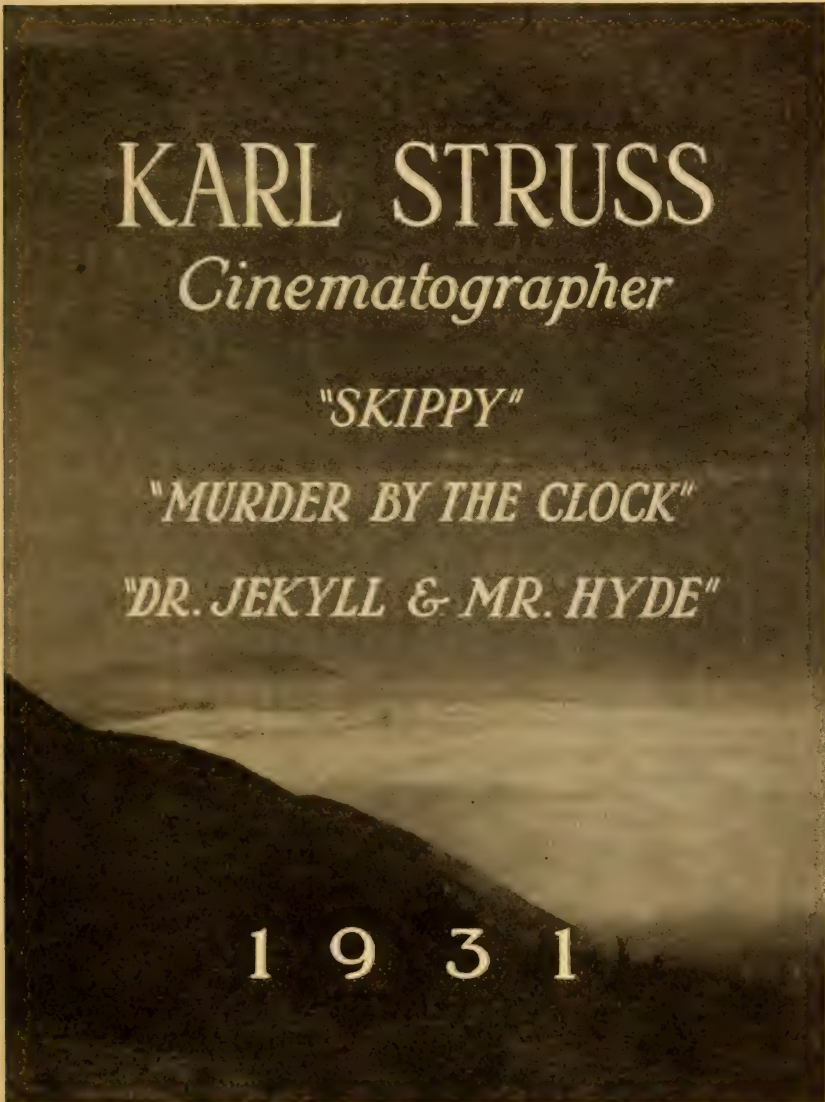
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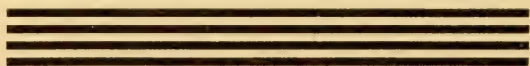
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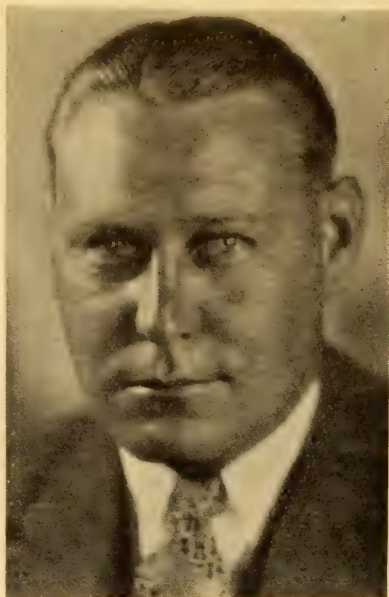
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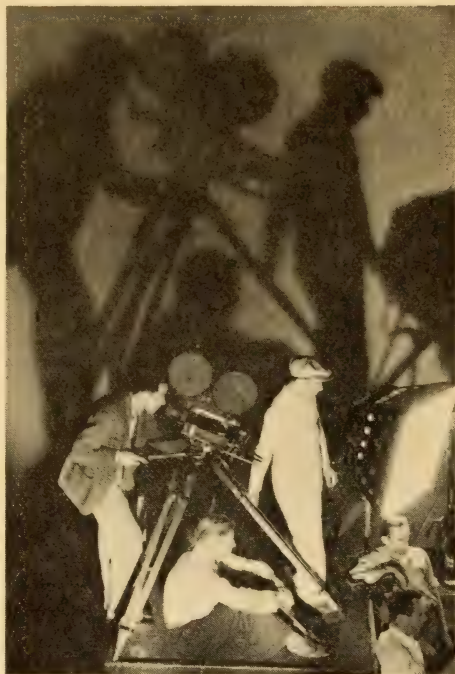
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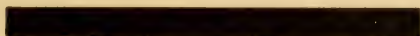


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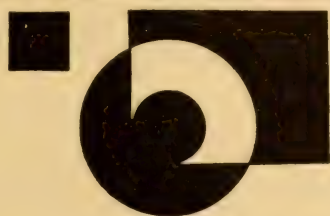
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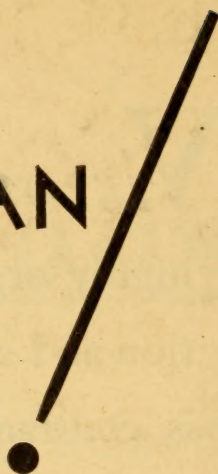
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